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MODULAR WASTEWATER TREATMENT SYSTEM DEMONSTRATION FOR THE TEXTILE MAINTENANCE INDUSTRY

Gary Douglas

Envirex, Incorporated

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Data ~~was~~ were obtained on effluent quality, sludge volume, chemical costs and other operating costs for industrial laundry wastewater, linen laundry wastewater, and uniform laundry wastewater. The final effluent of the linen and uniform laundry wastewater treatment met municipal sewer ordinance requirements for grease and heavy metals. Wastewater suspended solids and BOD were also significantly reduced, so that high municipal sewer surcharges would not be imposed. The effluent from the industrial laundry wastewater treatment did not consistently meet municipal sewer ordinance standards.

Complete wastewater treatment operating costs were on the order of $0.80/cu m for industrial laundry wastewater, $0.66/cu m for uniform laundry wastewater and $0.40/cu m for linen laundry wastewater. It was concluded that the treatment system had applicability in treating laundry wastewater. (EPA)

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MODULAR WASTEWATER TREATMENT SYSTEM DEMONSTRATION FOR THE TEXTILE MAINTENANCE INDUSTRY

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Project 12120 FYV
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ABSTRACT

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A wastewater treatment system consisting of chemical treatment and flocculation facilities, dissolved-air flotation for solids-liquid separation, diatomaceous earth filtration for polishing the flotation effluent, and vacuum filtration dewatering of flotation scum was installed at a commercial laundry.

Data was obtained on effluent quality, sludge volume, chemical costs and other operating costs for industrial laundry wastewater, linen laundry wastewater, and uniform laundry wastewater. The final effluent of the linen and uniform laundry wastewater treatment met municipal sewer ordinance requirements for grease and heavy metals. Wastewater suspended solids and BOD were also significantly reduced, so that high municipal sewer surcharges would not be imposed. The effluent from the industrial laundry wastewater treatment did not consistently meet municipal sewer ordinance standards.

Complete wastewater treatment operating costs were on the order of \$0.80/cu m (\$3.00/1000 gal.) for industrial laundry wastewater, \$0.66/cu m (\$2.50/1000 gal.) for uniform laundry wastewater and \$0.40/cu m (\$1.52/1000 gal.) for linen laundry wastewater. It was concluded that the treatment system had applicability in treating laundry wastewater.

This report was submitted in fulfillment of Contract No. FYV 12120 by the Linen Supply Association of America and the Institute of Industrial Launderers under the partial sponsorship of the Environmental Protection Agency. Work was completed as of May 1973.

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SECTION I

CONCLUSIONS

The following conclusions can be made based on the data obtained from this study, as applied specifically to the operation at the Roscoe Laundry and their laundry formula:

1. Uniform and linen laundry wastewater, as defined in this report, may be treated by coagulation, dissolved-air flotation and diatomaceous earth filtration to meet most presently applicable sewer discharge standards.

2. Industrial laundry wastewater, as defined in this report, requires additional treatment, more consistent raw wastewater quality, or different treatment unit operation to meet municipal sewer standards consistently.

3. Calcium chloride coagulation followed by solids separation is an effective heavy metals separation technique for the laundry formula and wastewater investigated in this study. Laundries using different wash formulas may not find calcium chloride treatment effective.

4. The amortization and operation costs for this demonstration system were found to be as follows:

industrial laundry	$0.77/cu m (cubic meter) or $2.90/1000 gallons (gal.)(See Section V for detailed breakdown)
uniform laundry	$0.67/cu m or $2.53/1000 gal. (See Section VI for detailed breakdown)
linen laundry	$0.40/cu m or $1.52/1000 gal. (See Section VII for detailed breakdown)

Bulk chemical handling and alternate sludge handling facilities for linen laundries and bulk chemical handling for uniform and industrial laundries will reduce the operating costs for the demonstration system to:

industrial laundry	$0.71/cu m	($2.70/1000 gal.)
uniform laundry	$0.60/cu m	($2.29/1000 gal.)
linen laundry	$0.32/cu m	($1.21/1000 gal.)

5. Up to ninety percent removals of iron, lead, copper and zinc were obtained for uniform and industrial laundry wastewater. Mercury and cadmium are also significantly reduced in concentration by the treatment process.

6. The laundry washload of printer's towels had to be maintained at less than 15% of the wash poundage at any one time to insure effective operation of the treatment system.

7. The sludge volumes generated by various types of laundry wastewater are as follows:

industrial laundry	2% to 4% of the raw waste volume
uniform laundry	1% to 2% of the raw waste volume
linen laundry	0.4% to 0.8% of the raw waste volume

8. No sewer surcharges will be incurred for linen laundry or uniform laundry wastewater treatment system effluent at this plant. A surcharge might have to be paid for the industrial laundry wastewater treatment system effluent.

The following conclusions can be made based on the data obtained from this study, regarding laundry wastewater treatment in general:

1. Wastewater treatment is not cheap or easy, but is a complex problem requiring resolution by a competent engineering firm.

2. As the complexity of the wastewater decreases, the treatability and consistency of treatment improve considerably.

3. There is no economic benefit in treating laundry wastewater to reduce sewer surcharges for suspended solids and biochemical oxygen demand (BOD), as treatment costs will usually exceed the surcharge. If a linen wastewater treatment system is installed in a high sewer surcharge and water cost area, treatment conceivably could produce cost savings, but this would be an unusual situation.

4. Wastewater age is a significant variable in designing linen laundry treatment systems. Bench tests for linen wastewater should be performed on the freshest samples possible to prevent significant changes in wastewater treatability from occurring.

5. Wastewater reuse has potential in producing wastewater treatment cost savings dependent upon water costs.

6. Most laundry wastewater treatment installations will have to be custom designed from mechanical and configurative standpoints due to space limitations of many plants.

7. Wastewater reuse is feasible with a separate water storage and heating system for the wastewater treatment system effluent. Only city softened water should be used for boiler feed water. Separate programming of washing machines for effluent water is also required if it is not feasible to use this water for final rinses.

8. The wastewater effluent is good enough to clean articles without harming them, but is high in dissolved solids and calcium hardness, thus limiting its reuse potential. The presence of dyes can also limit the water's reuse value, as this is not removed in the treatment process. The water will have to be softened to be reused in the laundering process.

9. If the wash load of a laundry is seasonal, or the wash load proportions change radically over a period of time, e.g., industrial to linen, it must be known prior to designing a wastewater treatment system. A change in the wash mix can render a wastewater treatment system ineffective, as could the addition of new customers of industries radically different from the normal laundry clientele.

SECTION II

RECOMMENDATIONS

It is recommended that:

1. All laundries whose wash load is greater than fifty percent shop towels who are contemplating wastewater treatment, or who have a heavy metal problem, perform pilot plant (not laboratory) wastewater treatment studies in order to obtain design information for a large scale treatment system.

2. Equalization time at least equal to the length of one complete wash cycle be provided for all laundry wastewater treatment plants.

3. The treatment system concept employed for this demonstration plant be evaluated on a laboratory basis by all laundries considering wastewater treatment before installing a cheap "miracle" wastewater treatment system. Laundry owners should be aware that waste treatment is not easy or cheap, and be leery of package plants that fit into small areas.

4. Any treatment system installed be located away from areas of production activity, if possible, in order to facilitate maintenance; and that approximately 0.074-0.098 square meters (sq m) of floor space, with due consideration of head room, be allocated for each lpm of treatment capacity (3 to 4 sq ft/gpm capacity). This area requirement does not include space for wastewater equalization.

5. More information on the effect of laundry supplies on the treatment process be obtained to more adequately define the applicability of this treatment concept. Different wastewater coagulants may be required for different laundry formulas.

6. More information on the variability of laundry wastewater from plant to plant within the same wash category be obtained to establish if the variability is significant and if this significantly affects wastewater treatment results.

7. More extensive information on laundry water costs, treatment problems and profit margins be obtained so that waste treatment break even analyses can be performed for a variety of wastewater treatment cases to more completely define the magnitude and scope of the national laundry water pollution problem.

8. The above information be obtained from wastewater samples from as many laundries as possible by bench scale application of the demonstration system treatment concept so that treatment costs and effluent quality data are available for a variety of laundry circumstances. This same survey should obtain cost and wash formula information from each subject laundry such that treatment costs and a treatment system flow sheet can be developed for that laundry. If this is done for a dozen or more laundries, the scope of the treatment problem and the universality of the applicability of the demonstrated treatment concept can be accurately defined.

9. The same type of information as outlined in Recommendation No. 8 be developed for various laundry wash mixes, i.e., different percentages industrial, uniform, and linen.

10. The 1971 survey of Appendix A be periodically updated.

SECTION III

INTRODUCTION

The early portion of the 1970's has experienced a pronounced increase in governmental activity in the area of water pollution control legislation and regulation. In 1971, the 1899 Refuse Act was uncovered by the Congress and enforced by the Army Corps of Engineers. All industries discharging any water to a storm sewer or receiving body of water had to file for a permit to discharge with the Army Corps of Engineers and provide them with a detailed chemical analysis of their waste discharge. In 1972, the United States Congress passed a water pollution control bill aimed at eliminating water discharges by 1985. Many municipalities and counties are now tightening already existing water pollution control and sewer discharge ordinances or passing new ones. Local governments are doing this to comply with strict federal regulations, and are doing it in the easiest manner possible - by shifting the burden of cleaning the water to the producer of the wastewater. This has caused a variety of water pollution control problems for industry and has forced many specific industries to seek a solution to their water problems and provide waste treatment.

Not the least of those industries affected by these and related developments are commercial laundries of various types; linen, uniform, diaper, shop towel, etc. This is significant when one considers that laundry wastes from all sources make up 5% to 10% of all municipal wastewater(1). It can be appreciated that this percentage becomes even more significant when one considers that the suspended solids and biochemical oxygen demand (BOD) of laundry wastewater can be from 3 to 20 times higher than average domestic sewage, if the average suspended solids and BOD of municipal wastewater are considered to be 250 milligrams/liter (mg/l) (1)(2)(3). The concentration of these pollutional parameters is dependent upon type of laundry, type of laundry formulation used for cleaning, laundry location, general laundry housekeeping practices, laundry customer habits, etc. Other areas of concern for various laundry wastewaters include high alkalinity, color, grease, and assorted heavy metals. Generally, almost all laundries can be in violation of common municipal sewer ordinances regarding any of the above parameters, dependent upon a variety of considerations. High strength wastes in terms of BOD and suspended solids may also lead to excessive wastewater surcharges, a tax on wastewater strength, for certain laundries. Subsequent wastewater treatment conceivably could lower these charges, if the wastewater treatment cost was lower than the surcharges.

The above considerations led to the Linen Supply Association of America contracting the Rex Chainbelt Technical Center to do a bench scale waste treatment feasibility study for linen laundry wastes (2). From this study, several promising wastewater treatment processes were developed, not only for treating the wastewater for discharge, but also for reusing it in the wash process.

Based on the results of this study, it was decided to construct and operate a 757 liter per minute (lpm)(200 gallons per minute) laundry wastewater treatment demonstration system at a laundry washing a variety of articles. General laundry wastewater treatment feasibility could then be demonstrated for a variety of laundry wastes. Consequently, a project involving the installation, operation and evaluation of a laundry waste treatment system consisting of chemical treatment, dissolved air flotation, diatomaceous earth filtration, and vacuum filtration dewatering of residual sludge was initiated. (Development of this concept is completely outlined in Reference 2.) This project was funded, in part, by the Environmental Protection Agency Grant No. 12120 FYV and in part by the Linen Supply Association of American, the Institute of Industrial Launderers, and various other laundry organizations and institutions enumerated in the Acknowledgments. The resulting project was divided into two phases:

I. Design, Fabrication and Planning of Prototype Equipment
II. Operation and Evaluation of System

This report summarizes the work performed in the above two phases in the design, installation, operation and evaluation of a modular laundry wastewater treatment system coupled with water reuse in the laundering process.

SECTION IV

MODULAR LAUNDRY WASTEWATER TREATMENT SYSTEM DESIGN

DESCRIPTION OF LAUNDRY SELECTED FOR TREATMENT SYSTEM INSTALLATION

The laundry selected for the installation of the wastewater treatment system is located in Chicago, Illinois and washes shop towels, printer's towels, dust mops, table linen, kitchen towels, and continuous towels. The majority of the wash poundage is generally shop and printer's towels. These two items are also referred to as machine and print wipers respectively. When this project was initiated in March of 1971, the laundry's linen wash poundage amounted to about 25% of the total wash poundage. It was envisioned at this time that the linen wash wastewater would be segregated from the industrial portion of the wastewater so that the treatment system could be operated on either linen laundry wastewater or industrial laundry wastewater. Because of the low volume of linen cleaned in this plant, it was not possible to wash all linens at any one time and run the treatment system. Consequently, linen and industrial items had to be washed concurrently and a means developed to separate the two wastewaters.

An old basin of approximately 32.3 cu m (8,500 gal.) capacity was available for storage of linen wastewater. This could be segregated from the industrial wastewater by the usage of only certain washing machines for linen laundering and appropriate dams. Figure 1 shows a layout of the laundry and the trenches which carried the laundry wastewater. The rectangles marked "I" are industrial washing machines and those marked "L" are linen washing machines. All machines dump their loads of water into trenches directly beneath them. All these trenches drain into a small pit where the wastewater is pumped into a vibratory screen to remove large particles from the wastewater. The screened wastewater flows into the heat reclaimer pit where it is pumped through a heat reclaimer where zeolite softened city water is preheated by the hot wastewater. The wastewater then exits from the heat reclaimer and flows out into the city sewer.

For the purposes of this project, the trench under one of the linen washing machines was extended past the already used sewer discharge point to an old unused 30.5 centimeter (cm) or 12 inch (in.) sewer. This is marked by the

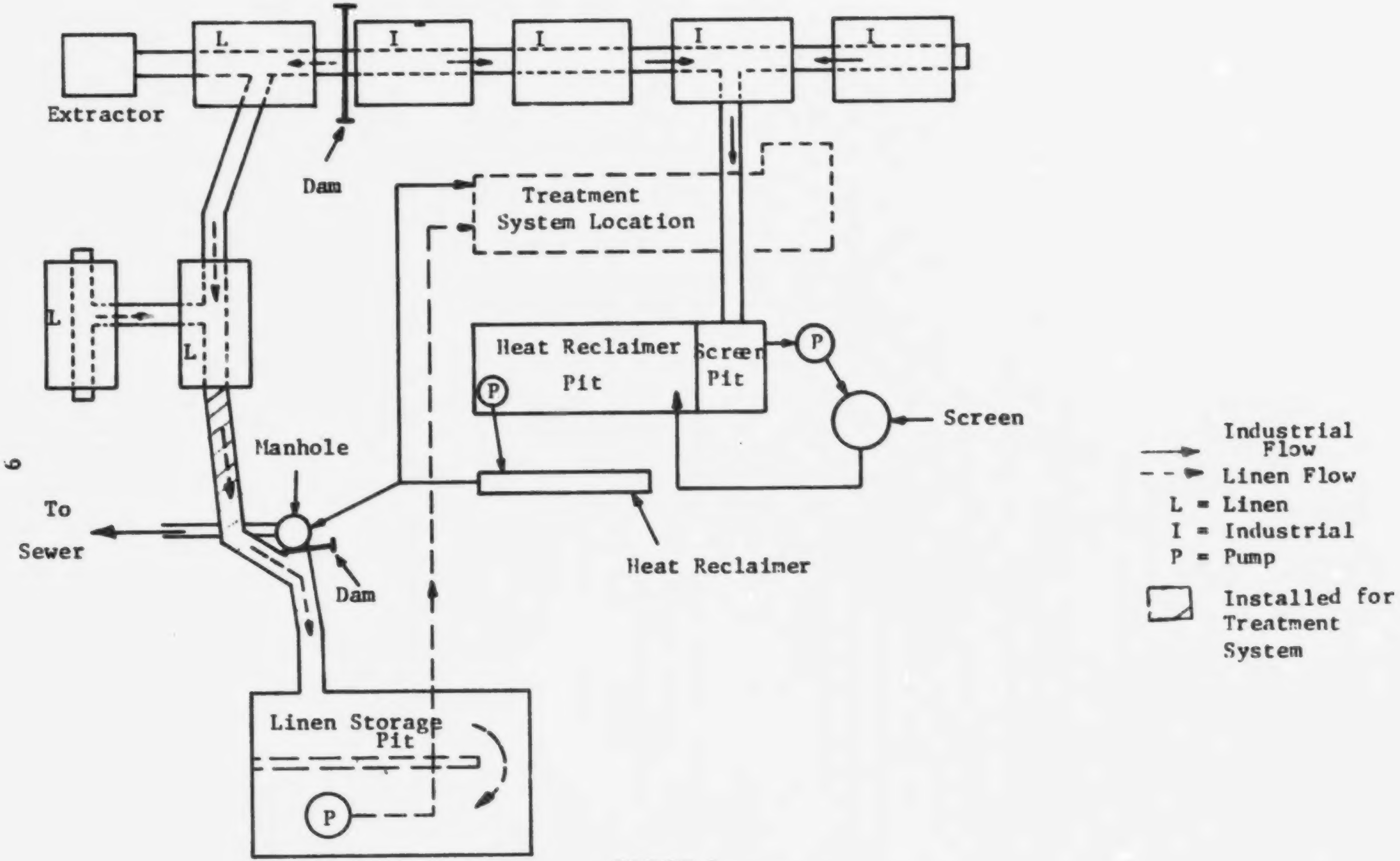

Extractor
L
I
I
I
L
Dam
Treatment System Location
L
L
Heat Reclaimer Pit
Screen Pit
P
P
Screen
Manhole
To Sewer
Dam
Heat Reclaimer
Linen Storage Pit
P
Industrial Flow
Linen Flow
L = Linen
I = Industrial
P = Pump
Installed for Treatment System

FIGURE 1
LAUNDRY WASTEWATER DISTRIBUTION SYSTEM

diagonal lines in Figure 1. By placing dams at the two points shown in Figure 1 and using those washers marked "L" for linen wastes, it was possible to separate linen wastewater from the industrial wastewater and store it in the 32.2 cu m pit. The industrial laundry wastewater was taken directly from the discharge side of the heat reclaimer into the treatment system. It could go either to the present laundry sewer discharge or the waste treatment system, or to the linen storage pit. A sump pump in the linen storage pit was used to pump the linen wastewater back to the treatment system, which was located as shown in Figure 1 between the heat reclaimer pit and the washing machines.

It may be noted here that the term "industrial laundry wastewater" throughout this report will be taken to mean that water emanating from the laundering of shop towels, printer's towels, and dust mops.

Softened city water, after passing through the heat reclaimer, flows to two water storage tanks where it is heated by steam coils. The steam is produced by hot water boilers. The preheated water is then brought up to the required temperature in the storage tank, and is then used in those cycles requiring hot water. Those portions of the wash cycle using softened cold water bypass the heat reclaimer system and go directly to the washers.

LAUNDRY OPERATION

This section of the report will serve to describe general operating practices of the laundry under consideration. The items cleaned by the laundry are hauled in by truck and deposited in drums or bags at an unloading dock. At this point, the wipers are taken to a counting station, where the wipers are manually counted and sent through a cage mill to remove metal chips or large pieces of refuse. The linen items are sorted elsewhere. These counted items fall into large bags that are then lifted onto a monorail system that conveys them to the washing machine area. Here the bags are emptied into the washing machines and the wash cycle started.

Each different item washed has its own laundry formula, which is the type and amount of cleaning chemicals required. These chemicals are referred to as supplies. For wipers, this laundry utilizes a formula consisting of alkali to swell the fibers of the cotton cloth to help loosen the dirt and grease present. This dirt and grease is referred to as the soil. Silicates are added to the wash at the same time to provide buffering between the caustic and cotton fibers. A nonionic detergent is also added to emulsify the oils and greases present. All these chemicals are added at one time during one washing operation; where a washing operation is defined as a portion of the wash cycle providing one batch of wastewater such as a suds operation, bleaching operation, or rinse operation. After this suds operation is completed, 6 to 11 rinses may follow to flush out the soil and supplies. Linen washing is similar except that bleach and a sour are also added. A sour is an acid chemical added in the last washing machine operation for pH adjustment. Starch is also added to linen wash loads, as well as other compounds, dependent on what is being laundered. Thus, each item laundered may utilize different cleaning agents, different proportions of cleaning agents, different wash operations, and different volumes of water per wash load.

Tables 1 and 2 present typical laundering schedules for shop towels and kitchen towels respectively. Schedules for other items would vary slightly from these. The first operation or flush is merely an initial rinse to remove readily loosened soil. The suds operation of Table 1 is that operation which emulsifies the oils and greases and loosens all the soil. The carryover is merely an extension of the suds operation in that a high percentage of the supplies initially added are still present. This operation takes advantage of that fact by utilizing the remaining cleaning ability of the suds chemicals. The carryover is followed by ten rinses to remove the used detergent and removed soil. The shop towels are then dyed, with salt added to set the dye. A final cold rinse also aids in setting the dye and removing excess dye. The operations outlined in Table 2 are similar, except that the linen wash load utilizes two suds operations and a bleach and sour operation. A mildicide is added with the sour. The initial break operation is similar to a suds operation except that no soap is added. This operation emulsifies the oils and greases present. The base oil compound added does this effectively. The soap is then required to remove stains, dirt, etc.

The laundered items are then unloaded from the washers into stainless steel tubs. The tubs are rolled into an extractor where excess water is squeezed out. This water also drains into the heat reclaimer pit. The clean articles are then taken to gas fired driers where the rest of the water is evaporated. After this operation, the clean wipers are folded and packaged into standard bundles and redistributed to the customers. The linen items follow a similar procedure.

The above considerations and Tables 1 and 2 demonstrate many items that could cause laundry wastewater to be highly variable in nature. The many different types of soil, the different laundry formulations for each soil type, and the different laundry operations as well as the batch type operation of each washing machine contribute to extreme variability in flow and contaminant concentrations. Each wash operation presented in Tables 1 and 2 discharges after its completion, such that with only one machine discharging, a series of wastewater surges would be received at some point with each surge being of different wastewater quality than the one preceding.

During the early part of this project, a survey of the laundry industry in general was made to determine water usage rates, water costs, washing practices, application of sewer ordinances, etc. This information was needed in order to determine the applicability of the wastewater treatment system to the laundry industry, both in terms of cost and practicality. However, this information does not have any direct bearing on the technical

TABLE 1

TYPICAL LAUNDERING SCHEDULE
FOR SHOP TOWELS

Washing Operation	Water Level (cm)	Temperature °F	Operation Length (min.)	Supplies
Flush	45.6	line	2	
Suds	20.4	190	15	NaOH, silicate & base oil
Carryover	20.4	190	4	
Rinse 1	45.6	190	2	
Rinse 2	45.6	190	2	
Rinse 3	45.6	190	2	
Rinse 4	45.6	190	2	
Rinse 5	45.6	190	2	
Rinse 6	45.6	190	2	
Rinse 7	45.6	185	2	
Rinse 8	45.6	175	2	
Rinse 9	45.6	165	2	
Rinse 10	45.6	155	2	
Dye	45.6	145	2	Dye
Salt	--	--	4	Sodium Chloride
Cold Rinse	20.4	100	2	

TABLE 2

TYPICAL LAUNDERING SCHEDULE FOR KITCHEN TOWELS

Washing Operation	Water Level (cm)	Temperature ^{o}F	Operation Length (min)	Supplies
Flush	45.6	Medium	4	
Flush	45.6	Hot	2	
Break	20.4		5	base oil, alkali
Suds	20.4	Hot	4	alkali, soap
Rinse 1	45.6	Hot	2	
High Suds	45.6	Hot	4	Soap, alkali
Bleach	25.4	150°F	7	Bleach
Rinse 2	45.6	Hot	2	
Rinse 3	45.6	Medium	2	
Rinse 4	45.6	Medium	2	
Rinse 5	45.6	Medium	2	
Sour	15.2	Cold	4	Sour, mildicide

evaluation of the wastewater treatment system installed at the laundry under consideration. Consequently, a report summarizing the results of this survey for industrial and linen laundries is presented in Appendix A.

The data from this laundry wastewater survey report will be utilized to compare treatment system effluent quality with required sewer discharge standards. It will also be used to compare laundry wastewater treatment costs to present laundry water usage costs and to determine the amount of money saved by reducing sewer surcharges on laundry wastewater BOD and suspended solids. It is common knowledge that municipalities charge industries for the amount of BOD and suspended solids they send to the municipal treatment plant that is above a defined level. This practice is well documented in the literature (4)(5).

WASTEWATER SAMPLING PROGRAM AND BENCH SCALE TREATMENT PLANT DESIGN

The laundry was first visited in March of 1971 and several times thereafter to obtain both composite and grab samples of the wastewater for laboratory bench scale testing for sizing the waste treatment equipment. Initial sampling was also designed to characterize the wastewater discharging from the plant into the city sewer.

Analytical results for three separate full shift, composite samples and one grab sample obtained from the subject laundry are presented in Table 3. The March 16 sample is the grab sample. As can be seen, the range of wastewater contaminant concentrations is quite large. It is evident that the wastewater contains an exceedingly high concentration of organic materials, hexane solubles, and an inordinate alkalinity. All analyses were performed in accordance with the thirteenth edition of Standard Methods for the Examination of Water and Wastewater (6). All analytical methods utilized are detailed and referenced in Appendix B.

These samples demonstrated a wastewater suspended solids variation between 1,946 and 2,380 mg/l and that the suspended solids may be 27% to 35% of the total solids. Thus the majority of the solids are dissolved, which is here defined as those solids passing through a 0.45 μ membrane filter or a standard Gooch crucible with a glass fiber mat in it. Analysis of samples other than these demonstrated that 70% to 90% of the total organic carbon (TOC) was associated with the suspended material (see Table 6).

A good portion of the TOC would be expected to be associated with the hexane solubles that were measured. The hexane soluble material for the most part was emulsified oils and greases and a small portion of free oil. It is possible that during the suspended solids analyses that a portion of the hexane soluble material was measured as suspended solids due to absorption on the filter paper during membrane filtration, or absorption to the walls of a Gooch crucible and filter medium during glass fiber suspended solids analyses. This could lead to low soluble TOC analyses because of loss of what could be classified as soluble TOC in the filtration. The degree of emulsification of the wastewater makes it

TABLE 3

INDUSTRIAL LAUNDRY WASTEWATER CHARACTERISTICS OF FOUR SAMPLES

	Sample Date*			
Analysis	3/3	3/16	4/15	5/20
Total Solids, mg/l	6850	5990	7431	7245
TOC, mg/l	4400	2200	3050	3400
Total Volatile Solids, mg/l	3250	3290	3641	5284
Suspended Solids, mg/l	2287	2115	2380	1946
Volatile Suspended Solids, mg/l	1953	1920	2225	1458
Hexane Solubles, mg/l	493	1838	2229	245
pH, units	11.9	12.0	12.6	11.6
Total Alkalinity as $CaCO_3$, mg/l	1825	2200	3190	1050
BOD, mg/l	1695	--	2482	--
Phosphorus, mg/l as P	1.3	--	--	--
Silica, mg/l as SiO_2	900	1000	673	--
Total Dissolved Solids, mg/l	4563	3875	5051	5299

* 3 full shift composite samples & one grab sample for 3/16

difficult to determine the exact nature of the contaminants present. It is expected that some of the emulsified oils would pass a membrane filter and some be absorbed by the solids being filtered. Thus, some emulsified oils and greases would show up as suspended material part of the time, and some would not. If the same emulsion could not be completely broken by the procedure for hexane solubles in reference 6, then a portion of the emulsion may not be measured in the hexane soluble testing. Large greasy particulates would be measured as hexane solubles. These facts make it difficult to distinguish between the exact amounts of particulate soil and greases since some non-particulate matter may show up as suspended solids, and some particulates as grease. Likewise it may be noted that the wastewater contained a quantity of solvent materials which might interfere with waste treatment, but do not show up in any solids analyses measured by evaporating a portion of the waste at 102°C. At this temperature, some volatile substances present would evaporate with the water and not appear as total solids.

A typical sample of the wastewater is a black or dark colored colloidal suspension which does not settle at all upon standing for many days. The wastewater can best be described as a thin oily mud. The material that comprises or contributes to the wastewater contaminants may be any material present in the shop towels and printer's towels being washed. The types of materials which may come from the machine wipers include greases and oils from tool and die operations, filling stations, and all types of factories where shop rags are utilized. The print wipers may contain paints, varnishes, lacquer, latex rubber, ketone solvents, or inks utilized in catalog and candy wrapper manufacture, as well as carbon black and other materials utilized at newspaper printing plants.

One of the largest print wiper customers of the subject laundry was contacted in an effort to define the sources of organic pollutants in the wastewater. They reported that they routinely used over 30 hydrocarbon solvents, and over 300 dyes, pigments, and inks daily in printing fliers, catalogs, and the like. The laundry had dozens of such customers at this time. Thus, the laundry ends up with whatever product its customers may be using. Consequently, the variety of materials present in the wastewater is immense and emphasize the difficulty in interpreting the meaning of gross analyses such as total solids, total organic carbon and hexane solubles. These points, coupled with the analytical problems, should be considered in all discussions regarding industrial laundry waste treatment in this report. These same points emphasize the degree of variability that might be expected in the wastewater both hourly and daily.

Table 3 also demonstrates that this laundry has a good deal of suspended solids and BOD associated with it. Thus one of the project goals was to significantly reduce these contaminants in order to prevent sewage surcharges. Another project goal was to upgrade the laundry effluent so that it would meet an already existing Chicago municipal sewer ordinance regulating discharges, as well as to upgrade the wastewater for potential reuse in the laundering process. The standards of this ordinance are presented in Table 4. It is readily discernible that alkalinity and hexane solubles are definite problem areas, as well as the suspended and biologically degradable material. The wastewater did not contain much phosphorus as little synthetic detergent is used at this plant. In comparison with a medium strength sanitary sewage, the laundry wastewater is quite strong, as may be seen by comparing Tables 3 and 5. Table 5 presents wastewater characteristics for sanitary wastewater as reported by Babbitt and Baumann (7). Thus the laundry wastewater BOD is 8 to 12 times greater, the laundry wastewater suspended solids 6 to 8 times greater, and the laundry wastewater alkalinity 18 to 32 times greater than a medium strength sanitary sewage. It can thus be appreciated that this is indeed a high strength industrial waste.

To determine the degree of variability in an operating day, grab samples of the wastewater going to the sewer were taken every 10 minutes on March 3, 1971. All samples obtained were analyzed for total solids, total organic carbon (TOC), and pH. Selected samples were analyzed for suspended solids and soluble TOC. The results of the laboratory tests for pH, total solids, and TOC are shown in Figures 2, 3, and 4 respectively. Time zero occurs at the time the first sample was taken (7:30 am). The time thereafter represents the number of minutes after this sample was taken. From these curves, it can be seen that there is a great deal of variability with time for the TOC, total solids and pH of this waste stream. The large decrease in pH, TOC, and total solids at about 300 minutes occurred at lunch break when only the linen washing machines were dumping. The contaminant concentrations increase again after the lunch period is over. The total solids reached levels exceeding 15,000 mg/l and the TOC reached levels of 13,000 mg/l.

Figure 2 demonstrates the observed variability in the wastewater pH. It can be seen that the effluent pH was always between 11.0 and 13.0. Though this does not appear to be a large variation, one should keep in mind that this represents a variation of two orders of magnitude in hydrogen ion concentration. It is obvious that this extreme fluctuation would complicate any pH dependent chemical treatment processes.

Table 6 presents the balance of the analyses performed on these waste samples. These analyses indicated that the wastewater suspended solids may vary between 950 and 4,350 mg/l and were 26% to 40% of the total solids for those samples tested. The total dissolved solids content for the wastewater ranged from 1,550 to 6,545 mg/l. These analyses also show the large variability of the waste stream characteristics.

The degree of variability demonstrated in these samples would be intolerable in conventional biological or physical-chemical treatment plants. The large change in alkalinity would make pH controlled chemical dosages difficult, and shock organic loadings would interfere with most biological processes. This preliminary information demonstrated that wastewater equalization is desirable.

TABLE 4

CHICAGO SEWER MANDATORY DISCHARGE REQUIREMENTS

Parameter	Concentration (mg/l)
Boron	1.0
Chromium (total)	25.0
Chromium (Hexavalent)	10.0
Copper	3.0
Cyanide (total)	10.0
Cyanide (readily released at 150°F and pH = 4.5)	2.0
Iron	50.0
Lead	0.5
Nickel	10.0
Temperature not over 150°F	
pH	4.5 - 10.0 units
Zinc	15.0
Cadmium	2.0
Hexane Solubles	100
Mercury	0.0005

TABLE 5

TYPICAL MEDIUM STRENGTH
SANITARY SEWAGE

Parameters	Concentration, mg/l
Total Solids	500
Suspended Solids	300
BOD	200
Alkalinity (as $CaCO_3$)	100

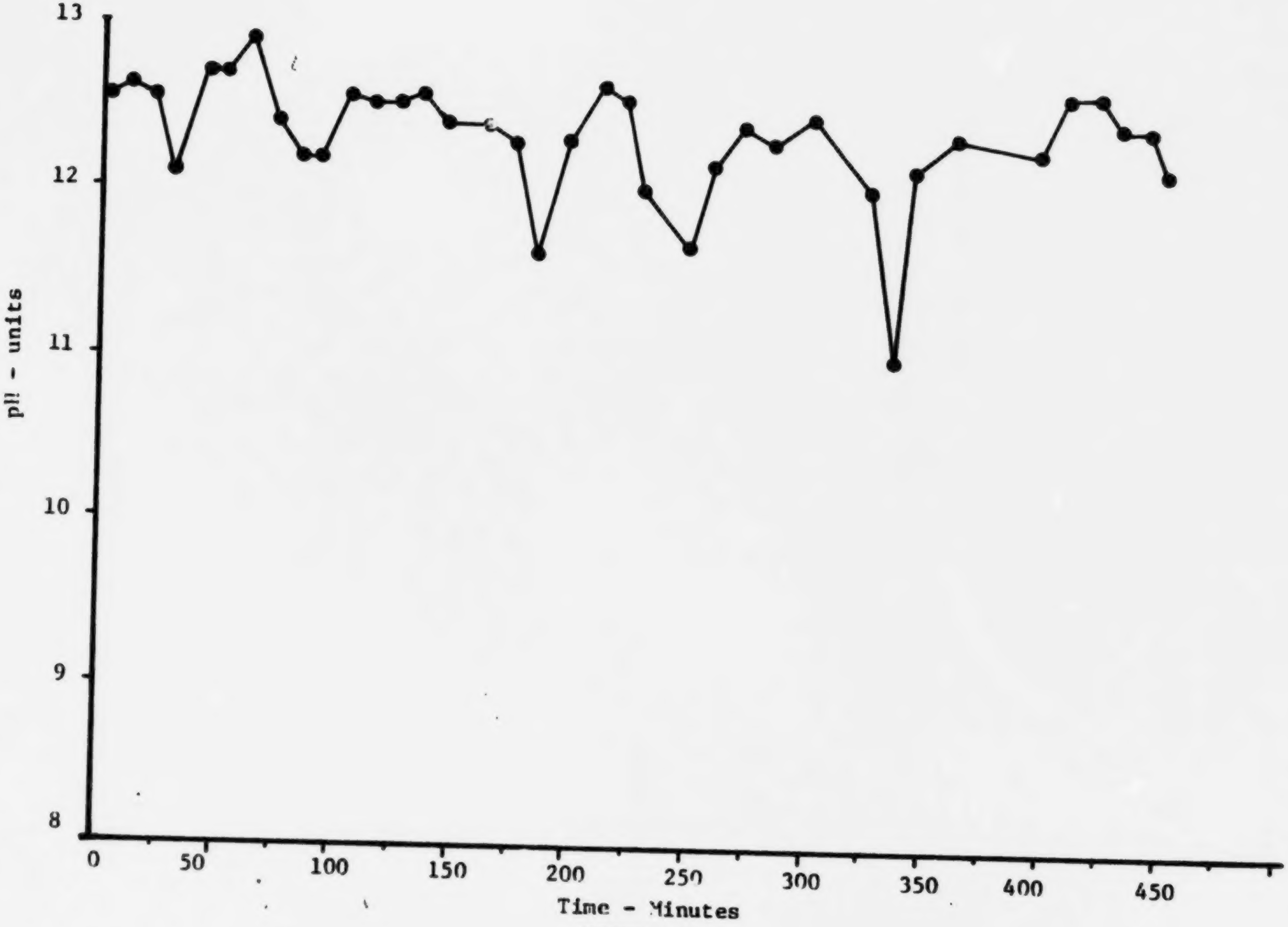


FIGURE 2

VARIATION OF pH WITH TIME FOR SEWER DISCHARGE ON MARCH 3, 1971

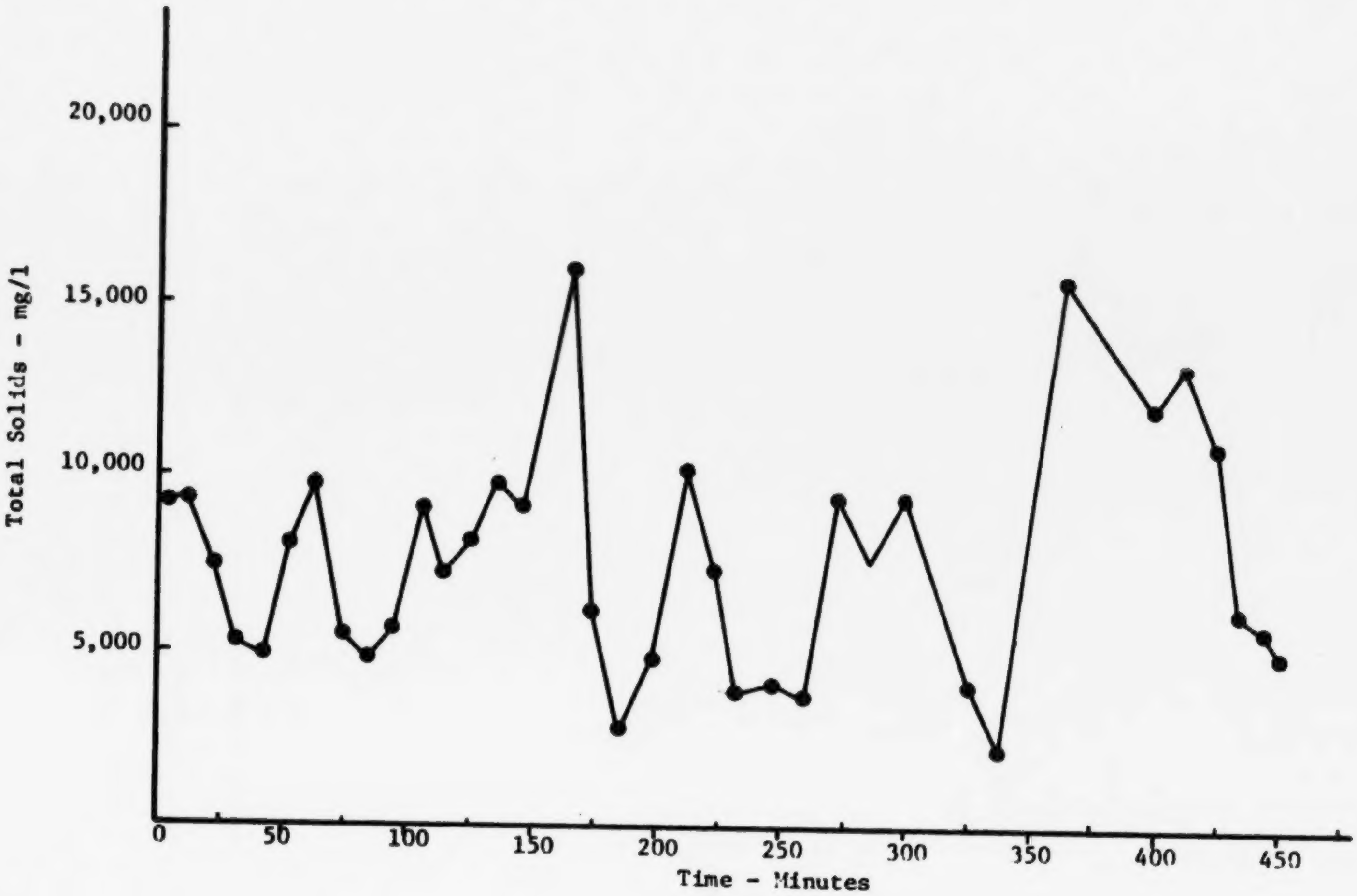


FIGURE 3
VARIATION OF TOTAL SOLIDS WITH TIME FOR SEWER
DISCHARGE ON MARCH 3, 1971

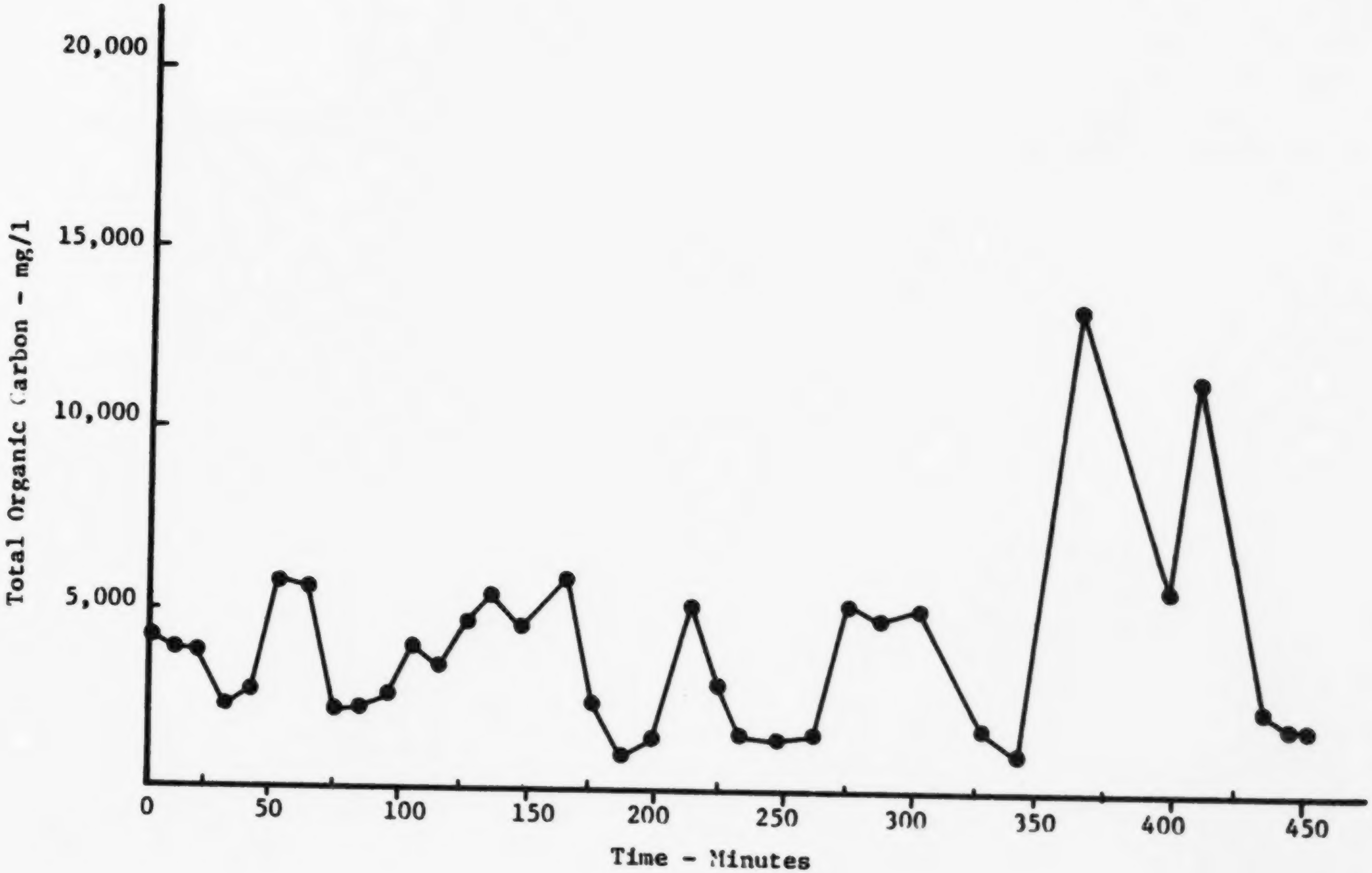


FIGURE 4

VARIATION OF TOTAL ORGANIC CARBON WITH TIME FOR SEWER DISCHARGE ON MARCH 3, 1971

TABLE 6

WASTEWATER ANALYSES OF VARIOUS GRAB SAMPLES OF MARCH 3, 1971

Time - Minutes After First Sample	Suspended Solids (mg/l)	Total Dissolved Solids (mg/l)	Soluble TOC (mg/l)	Percent Soluble TOC
0	2920	6230	--	--
10	--	--	370	9.3
50	2100	5978	--	--
80	--	--	725	33.0
158	--	--	835	14.2
178	950	1730	194	19.4
250	1150	1550	--	--
385	--	--	1208	21.4
409	4350	6545	--	--
435	1660	3205	365	18.8

Wash Operation Sampling

Further sampling at the laundry was performed to characterize the wastewater emanating from the washing operations of various articles and to identify the major pollutant contributors. It was desirable to establish with which articles and in what wash operation the majority of the pollutants evolved as well as to obtain an idea of the amount of contamination generated by a unit mass of a particular item. Grab samples were obtained from each machine dump for the entire washing cycle of print wipers, machine wipers, and dust mops. Due to the nature of the laundering cycle, each load of water is well mixed by the washer action. Therefore, a grab sample will be an excellent representation of the wastewater characteristics generated during that particular washing cycle (8). All samples obtained were analyzed for total solids, total organic carbon and pH. Selected samples were analyzed for suspended solids and soluble TOC.

The results of a typical series of analyses are presented in Table 7 for a 364 kilogram (kg) (800 pound) load of print wipers utilized by such industries as catalog and candy wrapper manufacturers. The results of eleven other sampling cycles for different items displayed similar trends. The contaminant concentrations varied, however, depending on the article washed. From Table 7 it may be seen that there is a sharp increase in total solids, pH, and TOC after the flush. The flush is merely an initial water rinse. This reflects the addition of the supplies as well as the removal of contaminants in the wipers. After the suds there is a steady decrease of TOC, pH and total solids with each succeeding rinse. Graphs of these data in Figures 5 and 6 reflect this trend. All of the curves demonstrate a sharp increase after the flush followed by a steady decrease in contaminant concentration, as the contaminants are washed out at a decreasing rate. Tables 8 and 9 present similar trends for machine wipers and dust mops. The addition of dye in the next to last rinse in these cycles is reflected by an increase in total solids.

These curves clearly show the great variability of wastewater that may occur during the washing of one load of any item. Each wash operation is dumped independently of any other one, so that each machine dump may flow to some point as a slug. Each dump is separated by a period of two minutes or more. It can be appreciated that a discharge of this type could cause a very significant variability in wastewater characteristics, even with several machines operating together, when the various washing machines are cleaning different articles from many different laundry customers. This reflects the difficulty one might have in chemically treating this waste unless alternate provisions, such as wastewater equalization, are made. This type of information can prove to be very useful in designing laundry wastewater treatment equipment.

A series of tests for silica were made on the different dumps of a load of machine wipers to determine the rate at which it is washed out of the wipers. Figure 7 demonstrates that while essentially all of the silica has been flushed from the wipers by the seventh rinse, the majority of the silica had been discharged during the first two operations.

TABLE 7

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION FOR 364 KGS OF PRINT WIPERS

Operation	Water Utilized (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Suspended Solids (mg/1)
Flush	1340	8,500	7,440	8.0	2,010
Suds	420	100,000	74,200	13.1	5,040
Carryover	420	58,000	49,300	13.2	6,320
Rinse 1	1340	9,125	28,100	12.9	1,900
Rinse 2	1340	9,000	19,600	12.8	1,510
Rinse 3	1340	4,150	8,930	12.6	690
Rinse 4	1340	5,000	10,700	12.7	2,420
Rinse 5	1340	2,400	5,630	12.5	910
Rinse 6	1340	1,100	3,100	12.2	640
Rinse 7	1340	800	2,280	12.0	420
Rinse 8	1340	575	1,620	11.7	380
Rinse 9	1340	600	1,740	11.5	300
Rinse 10	1340	460	1,440	11.5	270
Rinse 11	1340	520	1,230	11.2	580

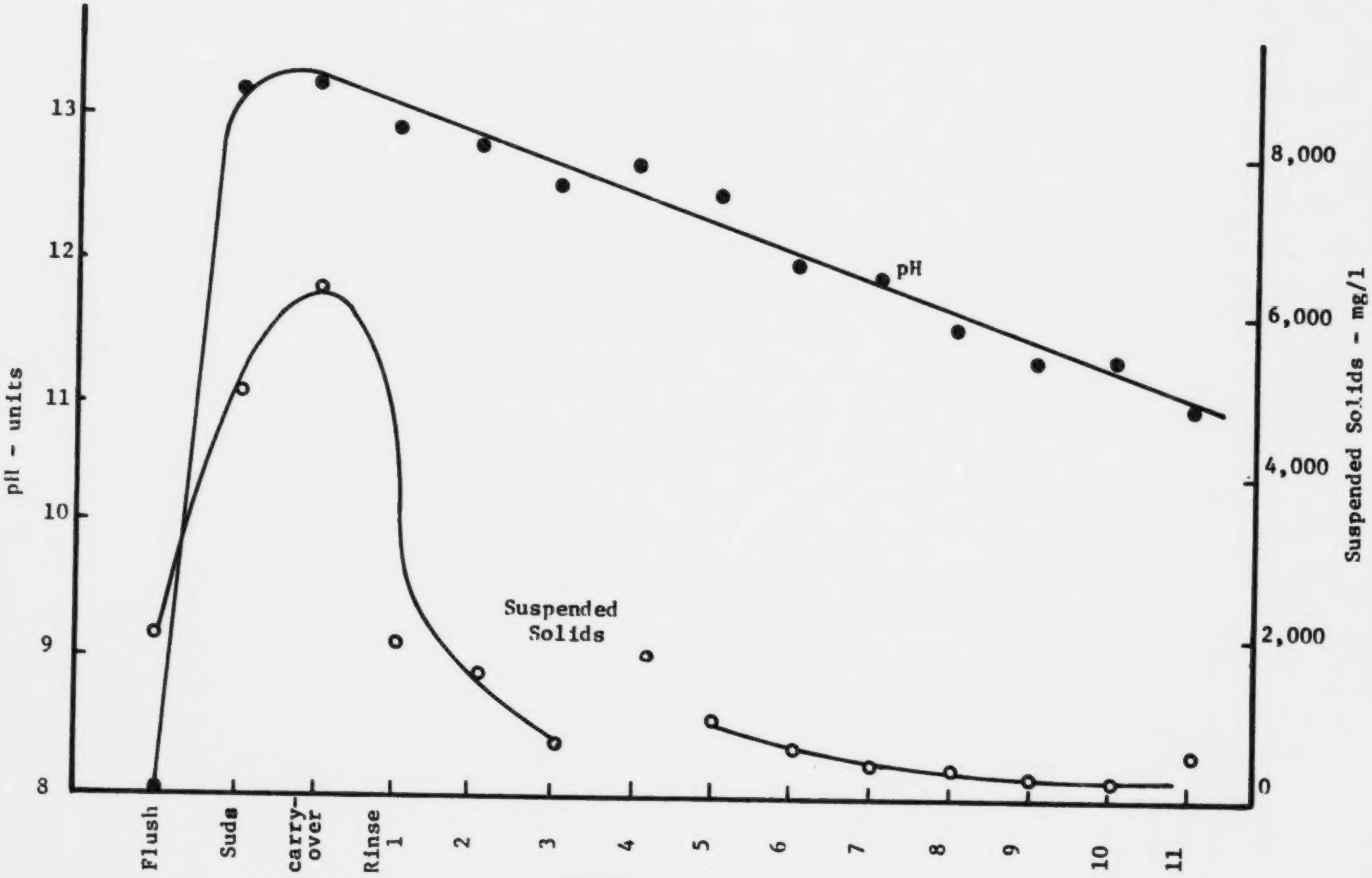


FIGURE 5
VARIATION OF pH, AND SUSPENDED SOLIDS WITH WASHING OPERATION
FOR A 364 KG LOAD OF PRINT WIPERS

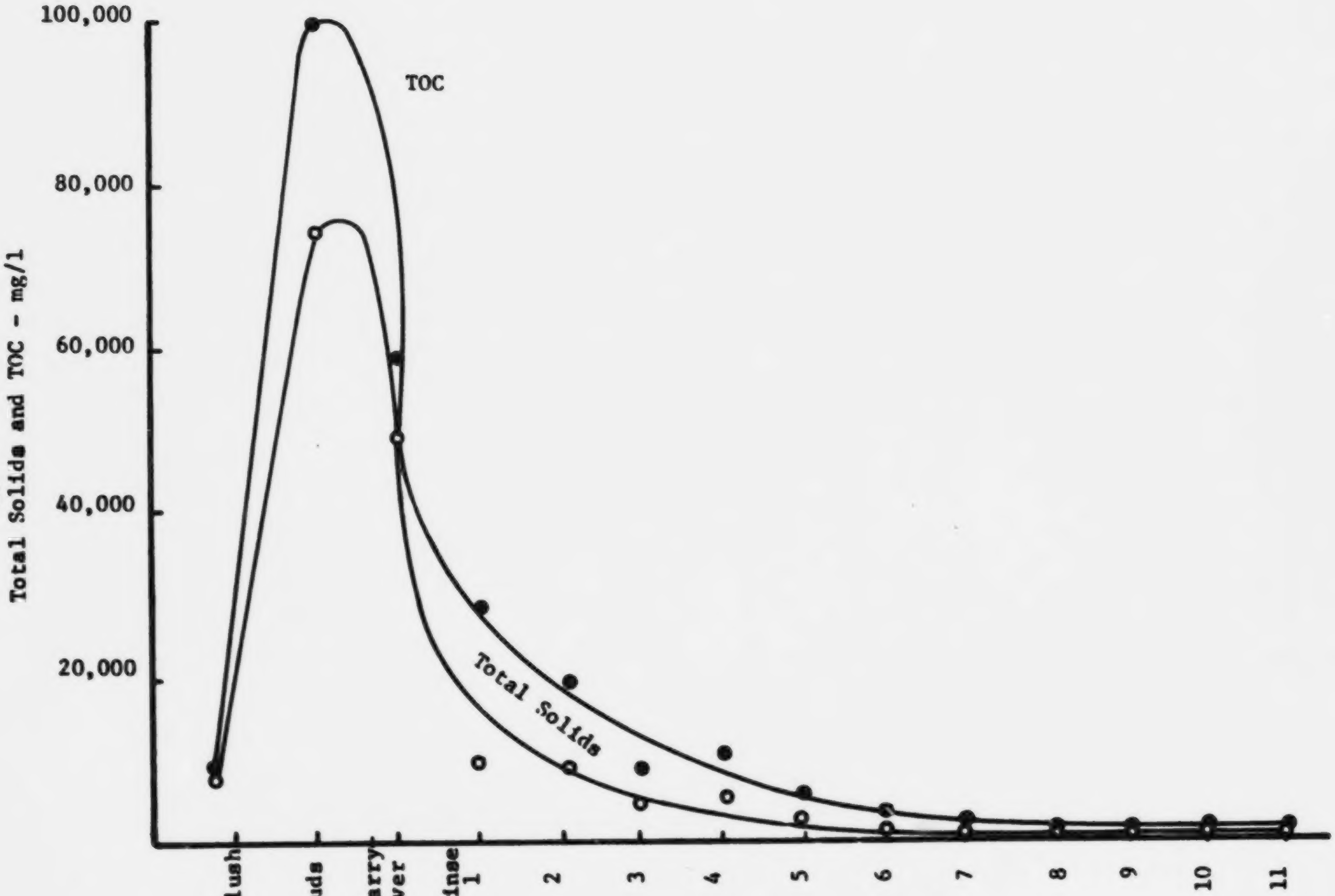


FIGURE 6

VARIATION OF TOTAL SOLIDS AND TOC WITH WASHING OPERATION FOR A 364 KG LOAD OF PRINT WIPERS

TABLE 8

VARIATION OF WASTEWATER QUALITY FOR MACHINE WIPERS WITH WASHING OPERATION

Operation	TOC (mg/1)	Total Solids (mg/1)	Grease (mg/1)	pH (units)	Silica as SiO_2 (mg/1)	BOD (mg/1)	Soluble TOC (mg/1)
Flush	18,000	51,087	18,000	8.3	--	<100	23
Suds	43,500	86,175		13	7,200	7,960	--
Carryover	30,000	80,725		13.1	5,000	6,825	
1 Rinse	13,900	38,746		12.7	3,000	4,500	
2 Rinse	4,000	13,031		12.5	920	900	
3 Rinse	2,000	8,649		12.3	660	380	
4 Rinse	850	3,368		12.0	325		
5 Rinse	730	2,261		11.6	200		
6 Rinse	470	1,240		11.2	145		
7 Rinse	810	1,233		10.6	70		
8 Rinse	236	818		10.4	62		20
9 Rinse	136	609		10.1	39		
Dye	288	2,252		9.9	44		
10 Rinse	194	1,277	191	9.7	30		13

TABLE 9

VARIATION OF WASTEWATER QUALITY FOR DUST MOPS WITH WASHING OPERATION

Operation	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Suspended Solids (mg/1)	Soluble TOC (mg/1)
Flush	910	3,731	9.0	1,420	520
Suds	12,500	40,543	13.2		
Carryover	15,250	50,591	13.1		
1 Rinse	9,800	32,740	12.9		
2 Rinse	5,950	18,940	12.8		
3 Rinse	4,920	10,541	12.7	2,990	775
4 Rinse	2,150	6,236	12.4		
5 Rinse	1,460	3,291	12.1		
6 Rinse	850	2,201	11.9		
Dye	650	3,686	11.3		
7 Rinse	304	1,987	10.9	685	69

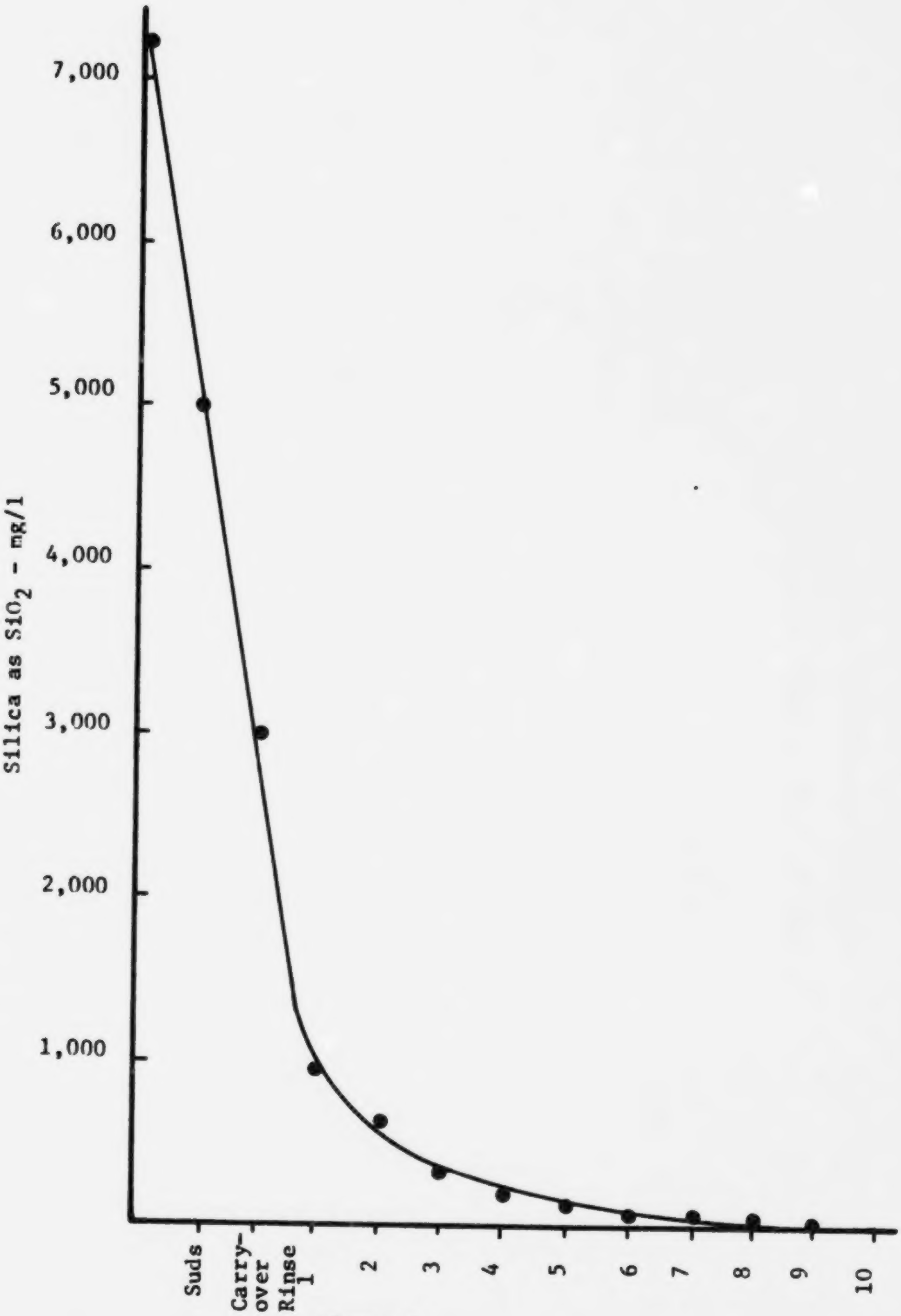


FIGURE 7

CARRYOVER OF SILICA IN SUCCEEDING WASH CYCLES
FOR A 364 KG LOAD OF MACHINE WIPERS

A total of 12.1 kg or 27.5 pounds (lbs) of silica as SiO_2 was measured coming from this load of wipers. This compares with the addition of approximately 3.6 kg (8 lbs) of silica based on laundry supplier's data. It may be noted that the water volumes of the different machine dumps were not measured, but were determined by the level of water in the washing machine, and may not be accurate. Likewise the addition of the required amount of silica is dependent on the people loading the washing machine. Some silica may have beeen present within the wipers themselves and would also increase the amount measured.

Table 8 lists the data plotted in Figure 7 as well as some analyses for wastewater BOD. It is apparent that the BOD also varied significantly with wash operation, but that after the carryover, it quickly decreases. A load of print wipers laundered on this same day was checked for soluble TOC for each machine discharge. It was found that 34.5% of the TOC generated was soluble.

Table 10 presents the wastewater characteristics of various final rinses sampled. In almost every instance, the water has a high TOC, total solids, and suspended solids level. From the standpoint of TOC and suspended solids, the last rinse has a water quality substantially poorer than domestic sewage which may be expected to have a suspended solids content of 250 mg/l and a TOC of 100 mg/l. All final rinse samples of the wipers and mops were visually dark and turbid. In some cases, the final rinse samples from the print wipers were visually indistinguishable from the first rinse samples. This raises the question of what quality water is necessary for washing wipers in the laundering process. The final rinse data indicate a high quality water may not be needed to launder wipers, and demonstrates potential reuse benefits of reclaimed water from the wastewater treatment system. As the pH and hexane soluble content of final rinses of machine wipers and print wipers do not meet the general standard of municipal sewer ordinances regarding discharges (pH = 10.0, hexane solubles = 100 mg/l), the entire volume of wastewater generated by these articles must be treated. In the wastewater reuse portion of this study, it was hoped that the question of required reuse quality would be resolved.

The data obtained from these individual washing operation samples was also used to compute the mass of wastewater total solids and TOC generated per 100 kgs of articles washed. The results of these computations are presented in Table 11. It may be noted that these results include the mass of TOC and total solids that are added by the supplies. The supplies generally add 2 to 5 kg of solids/100 kg of articles washed dependent on the amount of soil present. More supplies are required for heavier soil. The actual amount of solids contributed by the laundered articles is then approximately 2 to 5 kg less per 100 kg of articles washed than the results shown in Table 11. Computations based on the values in Table 11 and on actual laundry wash poundage, obtained on days when composite samples of the sewer discharge were obtained, predicted TOC and total solids twice as high as the composite sample contained. Other samples obtained later in the project and utilizing

TABLE 10

WASTEWATER QUALITY OF FINAL RINSES FOR VARIOUS WASHED ARTICLES

Article Washed	pH (units)	TOC (mg/1)	Total Solids (mg/1)	Suspended Solids (mg/1)	Hexane Soluble (mg/1)
Machine Wipers	10.4	400	1,660	445	--
Print Wipers, large	10.3	200	660	272	--
Print Wipers, small	11.2	520	1,230	580	202
Dust Mop	11.2	768	2,910	750	--
Dust Mop	10.9	304	1,990	685	
Print Wipers, small	10.0	236	640	440	--
Machine Wipers	9.7	194	1,280	--	191
New Wipers	10.8	676	2,700	--	--
Print Wipers, large	11.4	260	1,180	--	166

TABLE 11

ESTIMATED WASTE LOAD QUANTITIES FROM WASHING OPERATIONS

Article Washed	KGS TOC per 100 KGS Article Washed	KGS Total Solids per 100 KGS Article Washed
Machine Wipers	23.9 - 44.6	65.3 - 73.1
Dust Mops	12.0 - 13.0	39.7 - 40.9
Print Wipers, small	18.4 - 33.9	48.2 - 52.2
New Wipers, small	4.3	13.7
Table Cloths	0.9	4.9
Kitchen Towels	2.3	8.9
Print Wipers, large	29.3 - 41.9	62.0 - 66.2

average values for the TOC and total solids per 100 kgs articles laundered predicted the composite sample TOC and total solids to within 10%. Thus the daily variability of the wastewater is demonstrated in that the kilograms of soil washed out per unit mass of soiled article varies significantly.

The small print wipers shown in Tables 10 and 11 measured 45.7 cm by 47.5 cm (18"x18") while the large ones measured 45.7 cm by 76.2 cm (18"x30"). The large ones were used at large newspaper printing establishments, and tended to produce more TOC and total solids per kg washed than those used at smaller more varied printing plants. Whether the difference in the contaminant values is due to the industry or the wiper size is unknown. Similar analyses performed for linens demonstrated that they contributed little to the waste load at this plant. It is apparent from Table 11 that new unused wipers also contributed little to the wastewater TOC and total solids. Approximately 90% of the wastewater TOC and total solids come from the wipers and dust mops, with wipers contributing significantly more solids and TOC per 100 kgs of articles laundered than dust mops. Since larger amounts of wipers are washed per day than either dust mops or linens, it is apparent that these are the main sources of solids and TOC in the wastewater.

A series of BOD tests were performed on waste samples obtained for the machine wiper washing cycle in Table 8. The tests of the last seven rinses did not yield results because of improper dilutions and possibly unacclimated BOD seed. However, they could be reasonably estimated from the other data by plotting a curve similar to Figures 5 and 6. It was found that approximately 4.9 kg of BOD/100 kg of wipers washed was discharged during this operation. It is felt that this is low compared to the high TOC values obtained and may be caused by the presence of some bacteriologically toxic substances. Tests for suspended solids and soluble TOC on small print wiper discharges indicates that 5.8 kgs of suspended solids and 11.7 kgs of soluble TOC were dumped per 100 kgs of articles laundered. Thus the suspended solids measured were 12% of the total solids and the soluble TOC 34.5% of the total TOC for these print wipers, indicating the presence of a large amount of dissolved inorganic material. Average suspended solids analyses for various laundered articles are compared for two rinses and a flush in Table 12. It may be seen that the majority of the suspended solids come from machine wipers. Considering all the data it appears that the majority of the suspended solids are associated with the machine wipers and that a large portion of the dissolved solids are associated with the print wipers.

From the foregoing analyses, it is evident that the waste discharge of this laundry is highly variable in quality and strength, dependent on what is being washed. The shop and printer's towels produce the most contamination, and thus are the major problems in treating this wastewater, as 60% to 70% of the wash poundage consists of these items.

TABLE 12

SUSPENDED SOLIDS ANALYSES OF VARIOUS WASH OPERATIONS OF VARIOUS LAUNDERED ARTICLES

Article Washed	Average Suspended Solids of Flush (mg/1)	Average Suspended Solids of 4th Rinse (mg/1)	Average Suspended Solids of Last Rinse (mg/1)
Machine Wiper	7,700	5,110	455
Print Wiper, small	1,690	2,030	510
Dust Mop	1,415	2,290	718
New Wipers	605	--	240
Table Cloths	1,160	--	--
Kitchen Towels	2,410	--	--
Print Wipers, large	3,780	1,550	272

Thus, when designing an industrial laundry wastewater treatment system, the factors of what items and how much of each item are laundered must be known. Then with more data similar to that in Table 11, an approximation of the wastewater characteristics can be made for preliminary studies. Likewise, the supplies and class of customers are important in anticipating wastewater treatment problem areas. If the wash load of the laundry is seasonal, or the wash load proportion changes radically over a period of time (e.g., print wipers to linens), this must be known prior to designing a wastewater treatment system. Addition of new customers with different industrial operations than the normal clientele may also affect a change in wastewater characteristics, thus rendering a treatment system ineffective. It would not be necessary to go into as much detail as was done here in characterizing the waste, but an attempt should be made to identify the type and amount of soil associated with each separate article laundered in order to determine what will happen if the proportions of items change. This type of analysis can also provide information on the degree of wastewater variability.

Laboratory Bench Scale Chemical Treatment and Solids Separation Tests

The significance of the wastewater variability was reflected in bench scale chemical treatment and flotation tests conducted on both composite and grab samples obtained from the laundry's sewer discharge. Chemical tests in a preliminary feasibility study had indicated that alum and acid treatment appeared to offer the most promising results for linen laundry wastes (2). Consequently this was one of the chemical treatment systems investigated for industrial laundry wastewater.

Investigations for alum chemical treatment characteristics were carried out on three different wastewater samples of laundry discharge obtained on March 3, 1971, March 15, 1971 and April 15, 1971. The chemical characteristics of these three samples were presented in Table 3. The optimum alum-sulfuric acid dosages were determined by jar tests, the procedure for which may be found in Appendix B. Samples of wastewater chemically treated at various dosages with various chemicals were subjected to bench scale flotation tests to obtain design information as well as to observe the effect of the chemical treatment.

Table 13 presents the results of several bench scale flotation tests performed at various alum and acid dosages on the three samples. Jar testing determined the chemical dosage range to use as well as the rapid mix and flocculation times. All mixing was done by hand, the rapid mix by inverting the graduated cylinder several times and the flocculation by a gentle swirling with the wrist. Developed recycle of actual wastewater effluent was used as pressurized flow for all tests. It was determined that the best results were achieved by adding the acid first, then the alum, and then the polyelectrolyte, a nonionic one, with complete mixing in between each chemical addition. The flocculation period

TABLE 13

RESULTS OF BENCH SCALE FLOTATION TESTS USING ACID AND ALUM CHEMICAL TREATMENT

Test No.	1	2	3	4	5	6	7	8
Chemical Treatment Sample Date	3/16	3/16	3/16	3/16	3/3	3/3	4/15	4/15
H_2SO_4 (mg/1)	1270	1270	1760	1960	980	845	2940	2940
$Al_2(SO_4)_3 \cdot 18H_2O$ (mg/1)	2000	2000	800	450	2000	2500	750	500
Purifloc N11 (mg/1)	2	0	2	2	2	2	2	2
Rapid Mix Time, min.	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Flocculation Time, min.	1.5	1.5	1.5	2	1.5	1.5	5.0	5.0
Recycle Rate, %	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Rise Rate, meters/min. (mpm)	0.30	0.15	0.52	0.52	0.24	0.21	0.43	0.10
Detention Time, min.	8	8	8	8	8	8	10	10
Scum Volume, 1/1000 1	105	97	60	45	120	150	83	45
Sludge Volume, 1/1000 1	none	3	trace	trace	trace	trace	trace	trace
Effluent:								
pH	5.1	5.1	5.3	5.1	4.5	4.1	3.8	3.85
Suspended Solids, mg/1	3	37	48	25	12	24	105	112
Total Solids, mg/1	3750	3780	3980	4200	3660	3976	6000	6209
Volatile Total Solids, mg/1	405	505	473	524	524	560	934	932
TOC, mg/1	115	135	140	152	363	395	664	674
Silica, mg/1 as SiO_2	460	--	--	--	405	450	170	180
Conductivity, μmhos/cm	3600	--	3700	3900	--	--	--	--
Sulfate, mg/1 as SO_4	2000	--	2500	2400	--	--	--	--
Magnesium, mg/1 as $CaCO_3$	15	11	10	12	--	--	--	--
Grease, mg/1	27	--	--	--	--	--	--	--
Percent Reduction in:								
Suspended Solids	99.9	98.3	97.7	98.8	99.0	99.0	95.6	95.3
Total Solids	37	37	34	30	47	42	19	16
Total Volatile Solids	88	85	86	84	77	76	61	61
TOC	94.8	93.9	93.6	93.1	92	91	78	78

started with the last chemical addition. The effluent from these tests, though low in suspended solids, was turbid and colored. The effluent quality deteriorated as the alum dosage was reduced for the March 16 sample. This is best reflected by the effluent volatile total solids and effluent TOC data. The effluent suspended solids data in the table may be misleading since the untreated colloidal solids remaining in suspension are not measured as suspended solids. However, the scum volumes generated were considerably lower at low alum dosages.

Combinations of calcium chloride, sulfuric acid and alum were also tried. The addition of calcium chloride prior to treatment with acid and alum did not substantially reduce the amounts of acid or alum needed nor did it raise the pH at which the best floc was formed.

The addition of a polyelectrolyte to the waste treated with alum and acid or with calcium chloride was found to improve the rate of floc formation and the effluent clarity. No attempt was made to find the minimum amount needed, since the cost of the polyelectrolyte is small compared to the cost of the inorganic chemicals needed. Comparison of Tests 1 and 2 shows that the polyelectrolyte helped in the removal of suspended material. Considerable hanging floc developed without the use of the polyelectrolyte. An average of 98% of the suspended solids were removed in all tests along with an average of 89% of the TOC, indicating an association of the organic material with the suspended matter. In all cases, the rise rates were fairly rapid.

The sample obtained on April 15 did not demonstrate the same results as the previous samples, as both effluent TOC and suspended solids increased considerably at alum dosages of 500 to 750 mg/l. This testing demonstrated considerable variability inherent in the optimum chemical dosages, and that jar tests would have to be run in the field each day. The percentage reduction of contaminants occurring however, still looked impressive.

Concern was expressed as to the effect of the wastewater discharge variability on this type of chemical treatment. Consequently, grab samples of the wastewater going to the sewer were obtained at 10 minute intervals on April 15, 1971. All samples were analyzed for alkalinity. Bench scale chemical treatment tests were performed on many of the samples to determine the effect of wastewater variability on the chemical treatment process.

Figure 8 demonstrates the observed variability in the wastewater pH measured in the field as a function of time. It can be seen that the effluent pH was always between 11.0 and 13.5 Though this appears to be a small variation, one should keep in mind that this represents a variation of two orders of magnitude in pH since it is a logarithmic function.

The grab samples obtained were tested for chemical treatability using alum and sulfuric acid. It was initially anticipated that this chemical treatment could be performed within a small pH range utilizing a constant alum dosage. By controlling the influent pH to the treatment system with an acid feeder stroked by a pH meter, a constant pH could

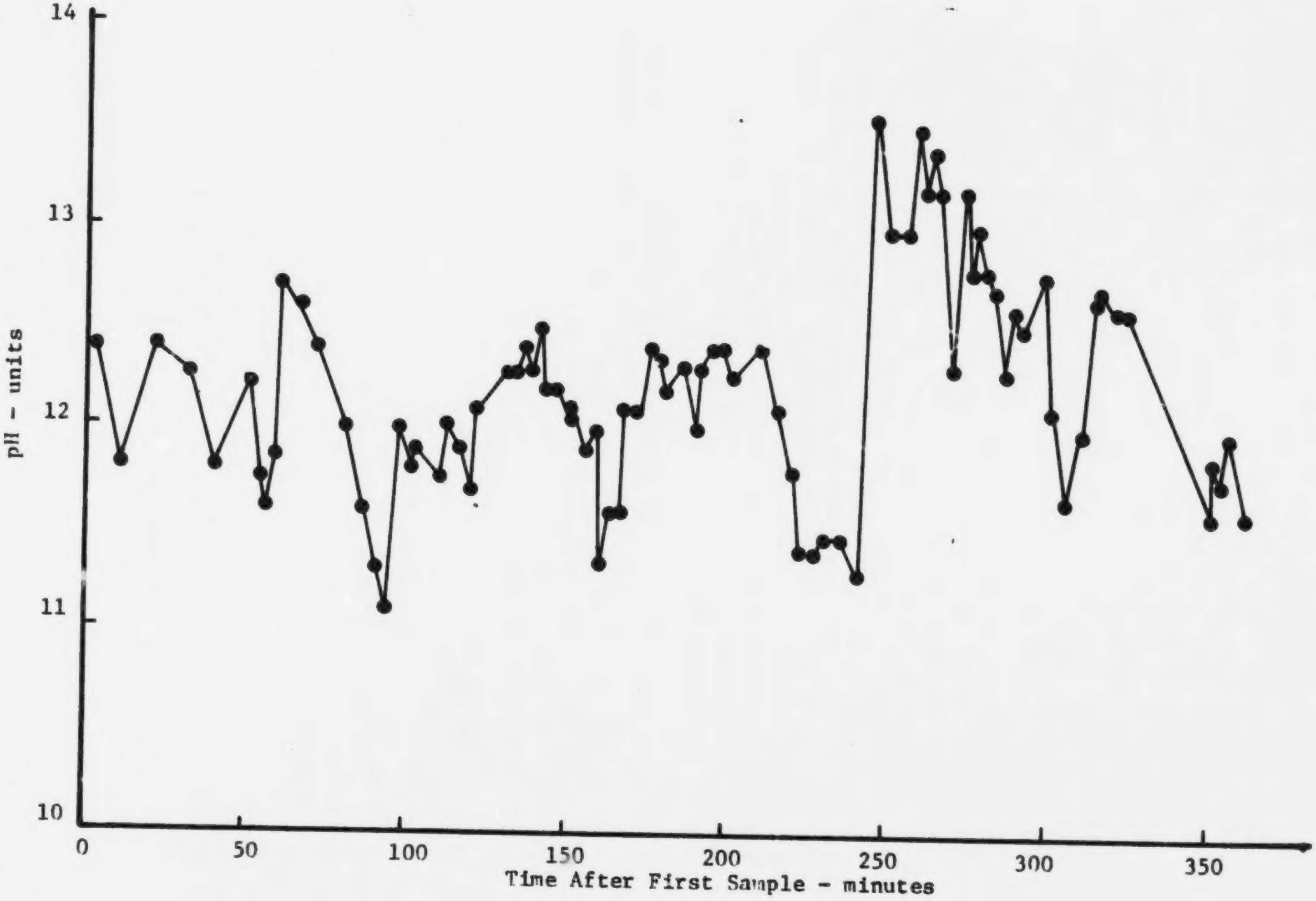


FIGURE 8

VARIATION OF LAUNDRY SEWER DISCHARGE pH WITH TIME ON APRIL 15, 1971 be maintained. Then by providing a constant alum feed, the wastewater could then be effectively coagulated. It was demonstrated, however, that neither pH nor alum dosage could be maintained at a constant level and provide consistently good chemical treatment. A summary of optimum alum-acid chemical treatment conditions for several of the grab samples in Table 14 illustrates this point. For samples with alkalinities near 500 mg/l, an initial pH of 9.0 is required for effective alum treatment. For samples higher in alkalinity, a pH of 4.0 to 4.6 is required. For some samples having alkalinities greater than 500 mg/l, alum dosages near 2000 mg/l are required. Thus it is apparent that, because the acid-alum treatment is very pH sensitive and the required alum dosage is highly variable, it was felt that consistent chemical treatment would be exceedingly difficult, and would require an equalization basin of inordinate size considering the space limitations of the laundry. Likewise the daily variability of the wastewater would require that jar tests be run to determine optimum chemical dosage. It was felt that this would be unrealistic in terms of the project objectives since it would take the good part of an operating day to obtain a representative sample from an equalization process, and would require laundries to hire a relatively skilled treatment plant operator to run these tests and observe the system. It appeared that alum-sulfuric acid coagulation was too sensitive to the characteristics of the wastewater to easily and consistently provide good chemical treatment. Therefore, sulfuric acid-alum treatment was rejected for treating this particular wastewater.

Calcium chloride was also evaluated as the flocculating chemical. It was found that 2000 to 2500 mg/l $CaCl_2 \cdot 2H_2O$ would provide consistent treatment with no pH adjustment in 85% of the April 15 grab samples tested. The floc formed was stable. Those wastewater samples with alkalinities of 1000 to 6000 mg/l were all treated effectively, as demonstrated in Figure 9. A least squares regression line is drawn through the data.

Bench scale flotation tests were also performed using calcium chloride and an anionic polyelectrolyte as coagulants. Calcium chloride is a known emulsion breaker, so its usage for this wastewater was indicated. Table 15 presents the results obtained on the previous mentioned wastewater samples. The resulting effluent was a pale orange reflecting the usage of a red dye for the shop towels. However, the subnatant was clearer than the acid-alum treatment had been, even though it appeared the suspended solids were slightly higher. (See tests 1 to 4 in Table 13.) The rise rates were about the same, while the sludge volume was considerably increased. Scum handling is discussed later in the report. The effluent TOC obtained was approximately the same for each chemical system.

Nalco 7720, a cationic emulsion-breaker, was also evaluated as a treatment chemical. It was found that 30 mg/l of this chemical utilized in conjunction with 100 mg/l bentonite clay at a pH of 3.8 to 4.8 would provide fairly consistent treatment for the April 15 composite sample. However, the floc formed by the emulsion breaker was very fragile.

TABLE 14

OPTIMUM ALUM AND SULFURIC ACID DOSAGES FOR WASTEWATER EFFLUENT GRAB SAMPLES OF APRIL 15, 1971

Sample No.	Alkalinity as $CaCO_3$ mg/1	H_2SO_4 Dosage mg/1	pH After Acid Addition	Optimum Alum Dosage mg/1	Final pH
1	2500	2450	5.3	500	4.6
2	1570	2150	5.6	500	5.0
10	528	196	8.8	500	7.2
17	970	1080	4.1	500	3.9
19	1472	1670	4.4	750	4.3
24	1440	1375	4.8	500	4.3
27	580	245	9.1	500	5.8
31	6150	6860	4.55	500	4.5
34	4690	4800	4.2	2000	3.9
36	1500	980	8.6	2000	5.0
37	2200	2150	4.6	500	4.2
39	1020	785	6.7	750	5.1

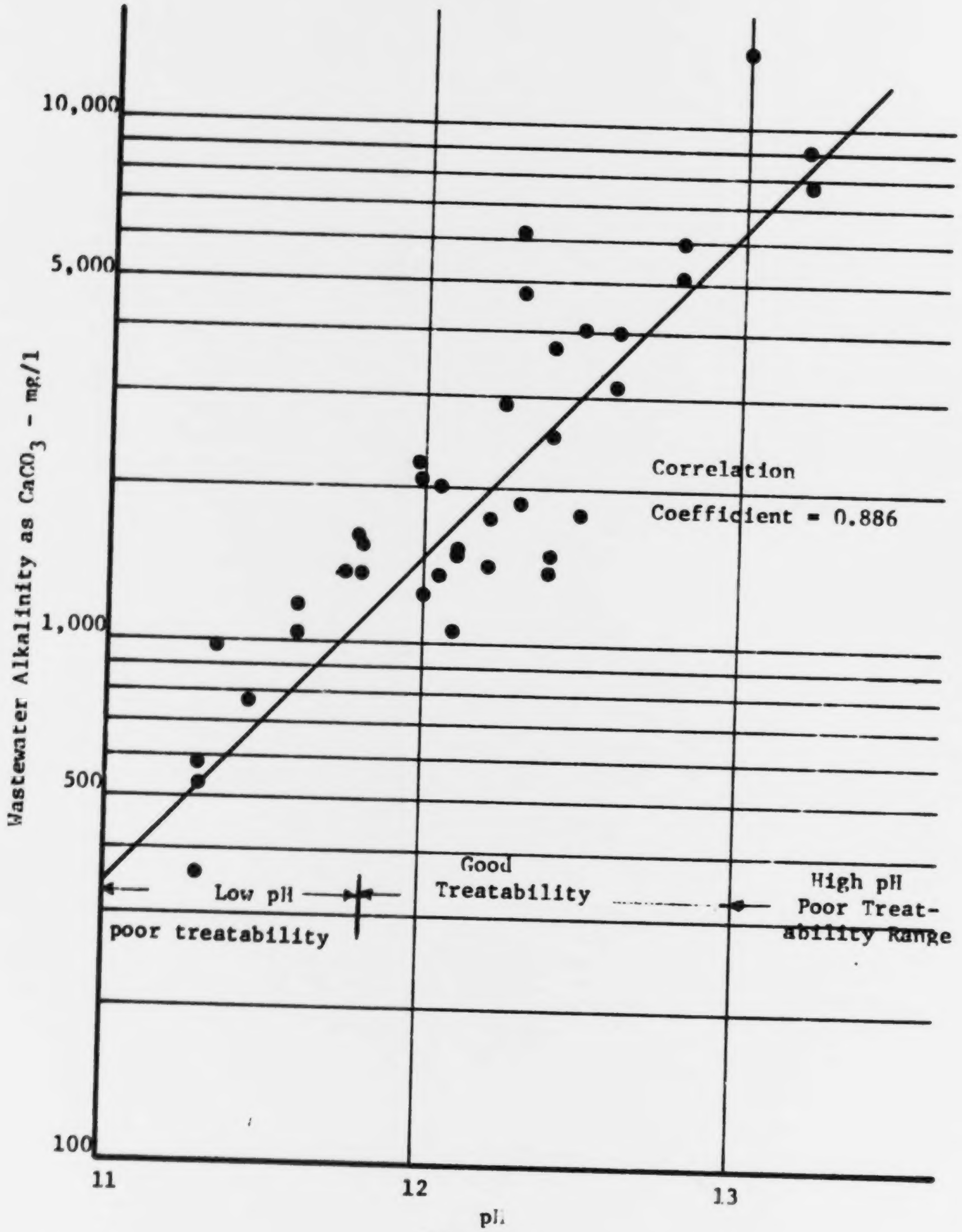


FIGURE 9
CORRELATION OF pH AND WASTEWATER ALKALINITY FOR GRAB SAMPLES OF APRIL 15, 1971

TABLE 15

RESULTS OF BENCH SCALE FLOTATION TESTS USING CALCIUM CHLORIDE CHEMICAL TREATMENT

Test No.	1	2	3	4
Date of Sample	3/3	3/16	3/16	4/15
Chemical Treatment				
$CaCl_2 \cdot H_2O$, mg/1	2000	2500	2000	1500
Purifloc A23,mg/1	--	--	--	1
Calgon 3000-A, mg/1	2	2	2	--
Mix Time, min	0.1	0.2	0.2	5.0
Flocculation Time, min	1.0	1.5	1.5	0.5
Recycle Rate, %	50	50	50	50
Rise Rate, mpm	0.52	0.15	0.30	0.12
Detention Time, min	8	8	8	8
Scum Volume, 1/1000 1	120	270	180	248
Sludge Volume, 1/1000 1	trace	none	trace	none
Effluent:				
pH	11.5	11.6	11.8	12.1
Suspended Solids, mg/1	79	32	65	59
Total Solids, mg/1	2830	3030	2920	4038
Volatile Total Solids, mg/1	644	533	600	1318
TOC, mg/1	540	142	192	613
Silica, mg/1 as SiO_2	160	60	--	43
Magnesium, mg/1	--	1	1	--
Ca, mg/1	--	--	--	31
Percent Reduction in:				
Suspended Solids	96	98.5	96.9	97.4
Total Solids	59	50	51	46
Volatile Total Solids	80	84	82	64
TOC	88	93.5	91.3	80

Table 16 lists bench scale flotation test results for this type chemical treatment. Hanging floc developed in the test, and the subnatant was very turbid, as in the acid alum testing. The scum volume generated was low but the rise rate was slower than the other chemicals. The emulsion breaker would not work without the addition of bentonite. A longer flocculation time was also required. The effluent quality measurements made were similar to that of the other tests in Tables 13 and 15.

Tests were also performed to compare the results of the alum and acid, calcium chloride, and Nalco 7720 emulsion breaking systems on a more direct basis. Consequently, samples obtained from each dump of the entire washing cycle of various articles on the March 16 trip to the laundry were composited for chemical treatment tests to determine which individual articles yielded wastewater that was the most difficult to treat. Each dump was composited in proportion to the amount of water utilized in the washing cycle. Chemical treatment tests utilizing alum, Nalco 7720, and calcium chloride were performed. The results of these tests are presented in Table 17. All treatment evaluations listed in the table are qualitative in nature.

From Table 17 it is self evident that the calcium chloride treatment provided the most consistent results of all the chemicals tested. The most difficult items to treat were the print wipers. From the above studies, it was determined that calcium chloride was the best coagulant that could be utilized for the demonstration system for chemical treatment of the laundry discharge. It was also evident that the calcium chloride was more tolerant of wastewater variability.

Many other chemicals were also tried in combination with many polymers of different varieties, but none were found to be effective. Table 18 lists other chemicals that were tried and rejected.

Laboratory Bench Scale Filtration Testing

The composite sample obtained on April 15, 1971 was a 200 l (55 gal.) barrel of wastewater. This sample was divided into two equal volumes with each individual volume subjected to flotation utilizing the pressure tank of a prototype flotation unit. Two separate flotations were performed in a 189 l (50 gal.) plastic container to obtain scum for Buchner funnel testing and vacuum filter leaf testing. One flotation was performed utilizing 30 mg/l Nalco 7720 after adjustment of the pH of the wastewater to 4.2, 100 mg/l bentonite clay, and 2 mg/l Purifloc N11; and the other utilizing 2000 mg/l $CaCl_2 \cdot 2H_2O$ and 2 mg/l Purifloc A-23. Tap water was used for recycle with the pH adjusted to that of the chemically treated wastewater. Fifty percent recycle was used. Approximately 20 l (5 gal.) of scum were obtained from each test. Solids analyses for the two scums are presented in Table 19. In both instances, the flotation scum had a suspended solids content suitable for vacuum filtration.

TABLE 16

RESULTS OF BENCH FLOTATION TESTING PERFORMED ON THE APRIL 15 COMPOSITE SAMPLE USING AN EMULSION BREAKER

H_2SO_4 Added, mg/l	2940
pH after H_2SO_4	4.1
Nalco 7720, mg/l	30
Bentonite, mg/l	100
Mix Time, min.	0.1
Flocculation Time, min	5
Recycle Rate, %	50
Rise Rate, mpm	0.08
Detention Time, min.	10
Scum Volume, 1/1000 l	68
Sludge Volume, 1/1000 l	0
Effluent:	
pH	4.1
Suspended Solids, mg/l	44
Total Solids, mg/l	5722
Volatile Total Solids, mg/l	713
TOC, mg/l	571
Ca, mg/l	24
Si, mg/l as SiO_2	170
% Reduction:	
Suspended Solids	98.0
Total Solids	36
TOC	81
Volatile Total Solids	80

TABLE 17

CHEMICAL TREATABILITY CHARACTERISTICS OF INDIVIDUAL LAUNDERED ARTICLES UTILIZING THREE DIFFERENT CHEMICAL SYSTEMS

Articles Washed	pH-Alkalinity(a)	Nalco 7720 - Bentonite Clay	Alum - Acid(b)	$CaCl_2 \cdot 2H_2O$(c)
Large print wiper used at newspapers	pH - 12.3 alk - 3577 mg/1 as $CaCO_3$	initial pH = 3.9 100 mg/1 7720 +300 mg/1 bentonite → very fine floc treatment - poor	initial pH 6.5 5000 mg/1 alum to pH 3.95 → no floc treatment - poor	3000 mg/1 → Good Floc Treatment - good
Small print wipers	pH - 12.6 alk - 6076 mg/1 as $CaCO_3$	initial pH = 3.9 +200 mg/1 bentonite → fine floc treatment - poor	initial pH - 4.6 2000 mg/1 alum at pH 4.3 treatment - poor	3000 mg/1 → fair floc treatment - fair
Dust Mops	pH - 12.5 alk - 4557 mg/1 as $CaCO_3$	initial pH = 7.0 30 mg/1 7720+ 100 mg/1 bentonite treatment - fair	---------------	2000 mg/1 treatment - very good
Machine Wipers	pH - 12.3 alk - 3185 mg/1 as $CaCO_3$	initial pH = 4.6 30 mg/1 7720+ 600 mg/1 bentonite treatment - fair	initial pH - 5.6 2000 mg/1 alum → small floc at pH 5.1 treatment - fair	2000 mg/1 treatment - good

(a) Composite samples of individual washing machine dumps for each article.
(b) with 2 mg/1 nonionic polyelectrolyte Purifloc N11.
(c) with 2 mg/1 anionic polyelectrolyte Purifloc A23.

TABLE 18

CHEMICALS THAT WOULD NOT TREAT LAUNDRY WASTEWATER EFFECTIVELY

Alum and Sulfuric Acid

Ferric Sulfate and Sulfuric Acid

Magnesium Chloride and Calgon 3000A

Nonionic Emulsion Breakers

Anionic Emulsion Breakers

Cationic Emulsion Breakers

Ferric Chloride and Sulfuric Acid

Ferric Chloride

Lime

TABLE 19

SCUM CHARACTERISTICS FROM TWO TYPES OF CHEMICAL TREATMENT FLOTATION BENCH SCALE TESTING

Chemicals	Emulsion Breaker	$CaCl_2 \cdot 2H_2O$
Total Solids, mg/l	38,400	61,100
Volatile Total Solids, mg/l	38,157	--
Suspended Solids, mg/l	18,800	55,600

The procedure utilized for the Buchner funnel and leaf testing may be found in Appendix B. Conditioning of the emulsion breaker scum demonstrated that lime, ferric chloride, and an anionic polyelectrolyte would provide a large visual floc. However, specific resistances, a measure of the ability of the sludge cake to impede water flow through the cake's pore structure, of 1.2 to 1.5 x 10^8 sec^2/gm were obtained with chemical dosages of 10% to 30% lime, 6% to 10% ferric chloride, and 0.05% to 0.1% anionic polyelectrolyte on a dry solids basis.

Other combinations of lime alone and ferric chloride alone did not appreciably lower these values. This compared with specific resistances of 2 to 5 x 10^7 sec^2/gm for ferric chloride conditioned digested sludge that was filterable (9). The specific resistance was thus relatively high for this sludge after chemical conditioning. Likewise the sludge was exceedingly compressible, and the cake pore structure readily collapsed near the end of each test creating a gelatinous cake and thus indicating possible vacuum filter cloth blinding problems. Blinding is here defined as the plugging of vacuum filter cloth pore openings with sludge solids such that that portion of the cloth can no longer pass water. This reinforced the rejection of Nalco 7720 for usage in the wastewater treatment system.

Buchner funnel testing of raw calcium chloride scum indicated specific resistances of 5.0 x 10^7 sec^2/gm. Utilizing conditioning chemicals of lime, ferric chloride and various polyelectrolytes not only did not improve this value, but in most instances increased the specific resistance. Consequently, it was decided no conditioning chemicals were needed to vacuum filter this sludge. Consequently, filter leaf tests were performed on the remaining scum without chemical conditioning for the purpose of filter sizing, filter medium selection, filtrate quality analyses, filter operating conditions, and filter cake solids determinations.

Fourteen different filter leaf tests were performed on the remaining sludge sample utilizing four different filter cloths whose properties are listed in Table 20. The monofilament was found to be unsuitable due to the presence of cloth fibers wrapping around the large openings and blinding the cloth. These could not be washed out. The cloth selected from the remaining three was number two of Table 20, because it had better discharge characteristics than either cloth 3 or 4 and provided better filtrate quality. The discharge from the cloth was excellent and it manifested no blinding problems during the testing. The final tests were performed utilizing this cloth. Because of cake cracking at 18% cake solids, no higher cake solids could be achieved. The cake formed was greasy, but was 6 millimeters (mm) or 0.25" thick and discharged readily. Therefore, a vacuum filter of the characteristics outlined in Table 21 was recommended. The size was based on a supply of 272.4 kg (600 lbs) of dry solids an hour, or on a chemically treated suspended solids concentration of 6,000 mg/l at 757 lpm (200 gal./min - gpm). Previous testing showed this to be a reasonably expected solids concentration.

TABLE 20

FILTER CLOTHS USED IN BENCH SCALE FILTER LEAF TESTS

No.	Type	Permeability cmm/sq m	Thread Count	Weave
1	Polypropylene Monofilament	too open	--	--
2	Polypropylene Multifilament	2.97	56x39	7/1 satin
3	Polypropylene Multifilament	4.07	58x46	2/2 twill
4	Polypropylene Multifilament	0.70	58x32	1/1 plain

TABLE 21

RECOMMENDED VACUUM FILTER CHARACTERISTICS AND OPERATING CONDITIONS OBTAINED FROM LEAF TESTS CONDUCTED ON FLOTATION SCUM

Filter Size	1.52 m (5 feet - ft) diameter x 2.13 m (7 ft)
Media	1PP 129-6009800 of Mero & Company
Pick-Up Time	40 seconds
Dry Time	80 seconds
Submergence	25% surface area wetted
Cycle Time	2.6 minutes
Expected Yield	26.4 kg/sq m/hr
Expected Cake Solids	18.0%

Another large sample of laundry wastewater was obtained on July 15, 1971. This too was subjected to flotation, as the first barrel of wastewater had been, utilizing 2000 mg/l $CaCl_2 \cdot 2H_2O$ and 2 mg/l Purifloc A-23 with 50% recycle. The scum generated had a total solids content of 4.24%. Leaf tests performed at the same conditions as Table 21 provided filter yields of 39.2 kg dry solids per square meter per hour (kg/sq m/hr) (8.0 lbs dry solids per sq ft per hr) at cake solids of 11%. A one minute filter cycle time could also be utilized to achieve yields of 65.9 kg dry solids per sq meter per hour (13.5 lbs dry solids per sq foot per hour). The cake cracked at 11% solids. This same problem occurred for the first sample that was leaf tested at 18% cake solids. These tests demonstrated that the filtration rate of the sludge could be expected to vary markedly from day to day, and that cake cracking is characteristics of the sludge. These tests confirmed the earlier recommendations for the vacuum filter.

The raw wastewater and flotation effluent of the above test was subjected to heavy metal analysis, as it now came to our attention that heavy metals could be a problem at many industrial laundries. Many sewer ordinances prohibit the discharge of heavy metals. Table 22 presents the results of these analyses. From Table 22 it can be seen that heavy metals are present in the waste at concentrations considerably greater than trace amounts, and that the heavy metals are reduced significantly by treatment with calcium chloride and flotation. This is most likely due to the high pH of the waste resulting in most of the metals being present as colloidal hydroxides. As suspended material these metals are then effectively removed. If a chemical treatment system was utilized that resulted in an operating pH near neutrality, many of these metals would solubilize and not be removed. This is another point in favor of calcium chloride as the primary flocculant, as it works effectively at a high pH. Because of this, the area of heavy metal removal was monitored throughout the rest of the project. Lead and mercury were the large problems at this laundry under the Chicago Sewer Ordinance.

Because of the nature of the solids remaining in the wastewater, it was evident that they would be readily amenable to diatomaceous earth (DE) filtration. The solids were very flocculant. A flotation effluent of about 100 mg/l suspended solids was expected. Bench scale testing of a mixed media filter consisting of 29 cm anthracite, 22 cm sand, and 7 cm of gravel demonstrated only 50% removal of the flotation effluent residual suspended solids at a hydraulic loading of 167 liters per minute per square meter (lpm/sq m) or 4.1 gal. per minute per sq ft (gpm/sq ft). There was no visual difference between the influent and effluent. Diatomaceous earth filtration of the same wastewater removed almost 100% of the suspended material and produced an effluent having a high degree of clarity though orange in color. It was felt this was required if the wastewater effluent was to be reused in this study.

Because diatomaceous earth filtration produced such good results, it was decided to perform bench scale leaf tests utilizing a diatomaceous

TABLE 22

REMOVAL OF HEAVY METALS BY CALCIUM CHLORIDE TREATMENT AND BENCH SCALE FLOTATION OF INDUSTRIAL LAUNDRY WASTEWATER

Metal	Influent Concentration mg/l	Effuent Concentration mg/l	Percent Removal
Iron	11.5	1.9	84
Lead	7.3	0.3	96
Cadmium	0.06	0.01	48
Copper	2.3	1.2	86
Zinc	2.08	0.29	70
Chromium	1.66	0.5	58
Cobalt	0.23	0.10	40
Mercury	0.05	0.03	40

earth filter on chemically treated raw industrial laundry wastewater. In this way, the flotation tank would be bypassed so that space could be conserved. The raw wastewater sample utilized was the May 20, 1971 sample of Table 3. A 2.54 cm (1 inch) filter leaf precoat of Johns-Manville Hy Flo Supercell was utilized at varying test conditions to get an idea of process feasibility. The support septum was the same cloth selected for the vacuum filter. The bench scale test procedure utilized may be found in Appendix B.

Table 23 presents the results of this testing. It is apparent that excellent filtrate quality was achieved. The cake solids content measured was in the range of 40% to 50%. Thus sludge volumes could be reduced threefold to fourfold as compared to the flotation, vacuum filtration system. However, due to the amount of diatomaceous earth required, the operating cost would be exceedingly high. The cost for diatomaceous earth alone at 17.6 cents per kg (8 cents per pound) would be between $0.30 and $0.48 per cu m ($1.15 and $1.83/1000 gal.) of raw wastewater plus chemical costs, sludge handling costs, and capital investment. The diatomaceous earth usage rate was calculated by assuming a 0.013 cm (0.005 in.) filter aid cut, a final cake thickness of 0.65 cm (0.25 in.), and a diatomaceous earch packed density of 340.2 kgs/cu m (21 lbs/cu ft). Consequently, though the process looked feasible and provided water of a high effluent quality, the concept was not pursued.

Investigations of sludge incineration were also pursued and found to be uneconomical. This study may be found in Appendix D.

RECOMMENDED FLOW SHEET

On the basis of the foregoing test work, it was decided that calcium chloride chemical treatment, dissolved-air flotation, diatomaceous earth filtration of flotation effluent, and vacuum filtration of the flotation scum would be able to treat the wastewater. On the basis of the test results with the calcium chloride, it was decided that no additional wastewater equalization would be required at this time. Figure 10 represents a flow diagram of the recommended treatment scheme. The filtrate from the vacuum filter was recycled to the rapid mix chamber, because it was felt that the filtrate would not be of high enough quality to discharge. The flotation effluent is neutralized with sulfuric acid prior to discharge to lower the pH to 10.0. The other process elements shown in the flow sheet are self-explanatory.

The design criteria utilized for the wastewater treatment system are presented in Table 24. All of these were developed from the bench scale treatment testing presented previously. It was felt that these design criteria would provide a system with enough flexibility to meet the project objectives. The expected solids generation data were also based on the bench scale testing. The DE filter was sized later with the aid of the filter manufacturer, and is reported on elsewhere.

TABLE 23

ROTARY PRECOAT VACUUM FILTER TEST RESULTS OF CHEMICALLY TREATED INDUSTRIAL LAUNDRY WASTEWATER*

	Test #1	Test #2	Test #3	Test #4
Pick-up Time, sec.	60	30	45	25
Dry Time, sec.	30	15	49	20
Cycle Time, min.	2	1	2	1
% Drum Submergence	50	50	37.5	37.5
Filtrate Volume, ml	277	160	240	153
Filtration Rate, lpm/sq m	14.6	16.9	12.8	16.3
D.E. Thickness Required, cm	6.3	7.6	6.3	7.6
Filter Area Required, sq m	51.6	44.6	59.4	46.5
Kgs DE/day	706	1130	814	1080
Filtrate Suspended Solids, mg/l	6	7	3	8
DE Cost, ¢/cu m	30	48	35	46

* Chemical treatment - 2,000 mg/l $CaCl_2 \cdot 2H_2O$, 2 mg/l purifloc A-23

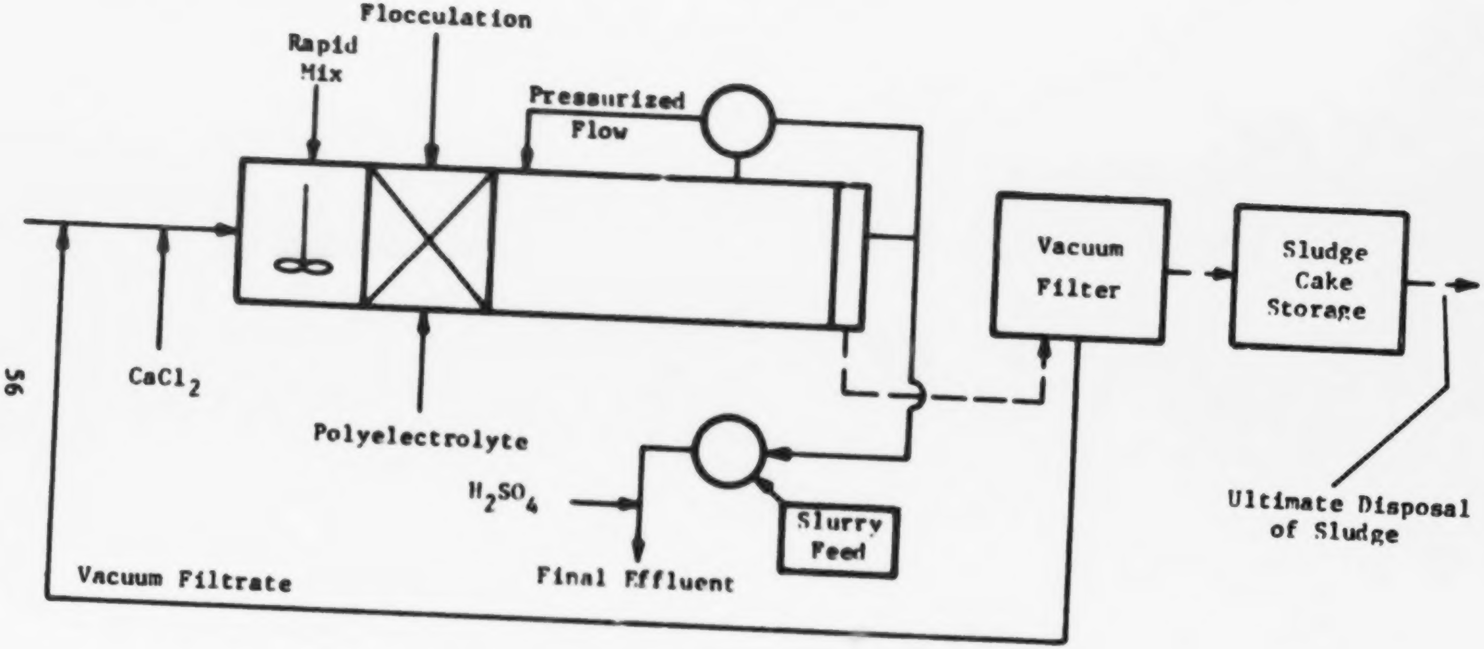

Rapid Mix
Flocculation
Pressurized Flow
CaCl$_2$
Polyelectrolyte
H_2SO_4
Slurry Feed
Final Effluent
Vacuum Filtrate
Vacuum Filter
Sludge Cake Storage
Ultimate Disposal of Sludge

FIGURE 10

INDUSTRIAL LAUNDRY WASTEWATER TREATMENT FLOW SHEET

TABLE 24

BENCH SCALE DESIGN CRITERIA FOR THE INDUSTRIAL LAUNDRY WASTEWATER TREATMENT SYSTEM

Item	
Chemical Treatment	1500 mg/1 $CaCl_2$ 2 mg/1 Purifloc A-23 Rapid Mix - 1 to 3 min. Flocculation Time - 5 to 8 min. Nine Hour Day
Waste Characteristics	pH range - 11.7 to 13.0 6000 mg/1 suspended solids after chemical addition
Flotation	Recycle - 50% Rise Rate - 0.15 mpm - 152 lpm/sq m Flow Rate - 757 lpm 150 1 scum/1000 1 wastewater Detention Time - 15 min. Scum Solids - 4%
Vacuum Filtration	Kgs dry solids - 2,450/day Metric tons wet solids - 12.25/day Cubic meters of sludge - 13.8 No Chemical Conditioning 10.2 sq m of filter Mero & Co. IPP 129-6009800 Filter Cloth

This completed the initial laundry survey and preliminary system design. The rest of this report is devoted to the sizing and operation of the recommended 757 l/min (200 gpm) treatment system on various types of laundry wastewaters.

FINAL SYSTEM DESIGN

At the beginning of the full scale design phase of this project, it was realized that floor area was going to be a definite problem in fitting in and designing a 757 l/min (200 gpm) demonstration laundry wastewater treatment system. The available area as shown in Figure 1 measured about 2.13 m (7 feet) wide by 12.8 m (42 feet) long with a maximum height of 3.2 m (10.5 feet). This area was to accommodate the flotation, vacuum filtration, and flocculation facilities. The diatomaceous earth filter was to be placed beside the vacuum filter shown at the widest end of the treatment system location outline of Figure 1. This occupied an area of about 1.5 m (5 ft) by 4.25 m (14 ft) including all tanks and pumps. Because the wastewater treatment system was located right on the laundry washroom floor, floor area was at a premium in this critical work area. Consequently, the design of the demonstration system had to be made to fit in this area. The overhead monorail system used to transport dirty laundry completely surrounded the wastewater treatment area thus making it physically impossible to build outside of this space even if it was desirable. All pumps, accessories, instrumentation and chemical storage was to be in this same area. The sludge from the vacuum filter was to be conveyed outside the building, over an alley, and into an open topped dumpster located in a fenced-in enclosure.

Therefore the design philosophy was to meet the bench scale design criteria as closely as possible, utilizing the available volume.

Flotation System Design

Because laboratory testing had showed that the chemically treated floc formed was exceedingly tough and readily filterable, the most critical portion of the system was the flotation solids separator rather than the flocculation and vacuum filtration facilities. Therefore, this piece of equipment was given priority in the allocation of the floor area. The dissolved air flotation basin was based on the criteria utilized by the American Petroleum Institute (API)(10). The major design parameters are overflow rate, detention time, horizontal velocity and depth to width ratio.

The basic principle of dissolved air flotation is to produce extremely small air bubbles (<100μ) which can be attached to the particulate matter in a wastewater and cause flotation and removal of the particulate matter. To provide these fine air bubbles a liquid stream is mixed with air under pressure. The pressure is then released through a weir type diaphragm valve to form the bubbles. The bubble laden stream is then mixed with the remaining wastewater to be clarified in a contained mixing zone within the flotation tank. This mixing zone has a detention time of approximately 90 seconds. The bubbles attach to the solids in this mixing zone. The bubble formation system is termed the pressurized flow system. The source of pressurized flow was the flotation effluent. Because of the possible presence of a significant amount of solids in the pressurized flow stream, a pressure tank without packing material was utilized. This avoided the potential clogging problems associated with a pressure tank packed with some form of tower packing to increase the air water interface.

The following discussion will delineate the process steps occurring in the flotation tank. Flotation effluent water is pumped into the pressure tank. Air is mixed with the water at the inlet to the pressure tank. The water level in the tank is controlled by a liquid level float switch. A slight excess of air is always added. If the water level becomes too low the air stream is vented to atmosphere to allow the water level to rise. There is a deflector baffle in the tank which spreads the incoming water and promotes a large air water interface for good air solution. The pressure in the tank is controlled by an air operated weir valve; this valve provides the proper back pressure as well as the required shearing action to form the small bubbles. This valve is controlled by a pneumatic controller. Once the pressure has been released and the bubbles formed, the bubble laden stream is mixed with the remainder of the raw wastewater flow. A 90 second mixing chamber is provided in the tank prior to entering the flotation zone. This allows time for bubble/solid attachment. Once the pressurized stream and remaining raw waste have been mixed, they enter the flotation zone of the tank where separation occurs. A skimming system skims the floated scum into one scum trough located at the inlet end of the tank, which conveys the scum to a vacuum filter.

The following set of design criteria were utilized:

flow rate	757 lpm (200 gpm)
hydraulic loading	114 lpm/sq m (28 gpm/sq ft)
horizontal velocity	0.68 mpm (2.23 ft/min)
pressurized flow rate	378 lpm (100 gpm)
operating pressure	2.81 kg/sq cm (40 psi)
detention time	10 minutes
depth to width ratio	0.5

The effective dimensions of the flotation tank were 5.36 m (17.6 ft) long by 1.82 m (6 ft) wide by 0.91 m (3 ft) deep. The outside dimensions of the tank were 1.37 m (4.5 ft) deep by 6.33 m (20.8 ft) long by 1.83 m (6 ft) wide. The width was fixed by the treatment system area, and the depth limited by the need of having room under the flotation tank for pumps and chemicals. It would have been desirable to make the tank larger to increase the detention time, but this was not feasible. Thus the detention time was 5 minutes less than desirable for the design flow rate.

Vacuum Filtration System Design

The size of the vacuum filter was selected from the bench scale testing to be 1.52 m (5 ft) in diameter by 2.13 m (7 ft) long. Consequently a rotary belt, continuously washed filter of this size was purchased from Amatek Inc. They also supplied the filter cloth belt, Amatek No. WNX-F4EO-RM8, which was a nylon belt with properties very similar to the one specified, but was no longer available. The cloth was a heavy spun staple with a 130 x 66 thread count, a weight of 391 gm/sq m (12.8 oz/sq yd) and a 7/1 satin weave. This cloth was identical in visual appearance to the specified cloth. City water was sprayed on the cloth to clean it on both sides.

Vacuum filtration is a solids dewatering process utilized for sludge volume reduction. In the process, the sludge flows into a vat within which rotates a cylinder with a plastic grid supporting the cloth filtration medium. As the cylinder rotates into the vat, a vacuum is applied drawing liquid through the cloth and retaining the sludge solids on the cloth. The total time one point on the drum is submerged in sludge is termed the sludge pickup time. The cylinder continues rotating out of the sludge vat still under vacuum such that the deposited solids are further dewatered. In the final step, the vacuum is released and a semi-dry solid is discharged from a variable speed driven roller. The time from the vacuum release to when the sludge rotates out of the sludge is termed the sludge dry time. Thus the process is continuous as long as there is sludge in the vat.

The filtrate or separated liquid goes to a receiver tank which is under vacuum from a 20 horsepower (hp) Bingham vacuum pump, sized for 8.50 cubic meter/min (cmm) of air. The liquid filtrate is pumped back to the rapid mix tank at a rate of up to 151 lpm (40 gpm) by a 3 hp La Bour centrifugal pump. The sludge was conveyed from the vacuum filter by a Moyno bridge breaker progressive cavitating filter cake pump rated at 45 lpm (12 gpm) and 3 hp. A Badger totalizing oscillating piston water meter is on the filtrate line to measure the volume of filtrate generated. The filter drum and discharge roller were driven by Reeves variable speed drives. The sludge level in the filter vat, often referred to as drum submergence, was controlled by a bubbler and a weir type diaphragm valve located on the sludge inlet line. Thus the sludge level could be maintained constant so that the filter vat would not overflow, and the sludge pickup time and consequently cake thickness is maintained constant. This is important because if the pickup time is too long, the cake will be so thick it will slough off the filter as it rotates out of the filter vat; and if the pickup time is too short, the filter will produce such a thin cake, it will not discharge. A thin cake is a form of filter blinding. Thus, as long as enough sludge is available, the optimum pickup time is maintained. Sludge was skimmed from the flotation tank into a 220 l (58 gal.) tank directly behind the perforated baffle. The discharge from this tank flowed by gravity to the vacuum filter. This was the line controlled by the diaphragm valve.

Diatomaceous Earth Filter System Design

Nine DE filter manufacturers were contacted in order to select the most economical and workable filtration system. A DE filter capable of handling the following wastewater characteristics was asked for:

suspended solids	100 mg/l
total solids	5,000 mg/l
temperature	120°F
grease	50 mg/l
pH	11.5 to 12.0
solid size	1.6 to 5.0 μ

The particulate size range was determined from a bench scale flotation effluent sample by a DE filter manufacturer.

The filtration elements or septums are coated with a layer of diatomaceous earth, a naturally occurring sedimentary rock consisting of millions of dead aquatic plants known as diatoms. Deposits of this siliceous material are found in California. These deposits are quarried, crushed, dried, calcined, and air classified into different grades. The final product is a mass of diatom skeletons and fragments of skeletons ranging in size from 5 to 50 microns. This material is exceedingly porous and adsorptive. Thus it is capable of removing small solids and oils.

After the septums are coated with diatomaceous earth, the process liquor is fed to the filter. Depending upon the suspended solids content of the liquid, a body feed is or is not required. Body feed is the addition of diatomaceous earth to the process liquor after the precoat. This builds up a layer of diatomaceous earth with the suspended solids and prevents the filter from clogging up quickly. It also provides more surface area for the filtration. After the pressure differential across the filter builds up to a predetermined level. 3.5 to 5.3 kg/sq cm, (50 to 75 pounds per square inch - psi) the filtration is stopped, and the liquid flow reversed to remove the diatomaceous earth and removed solids. This reverse flow, at a rate of 40.71 to 81.5 lpm/sq m (1 to 2 gpm/sq ft) of filter, lasts for 1 to 2 minutes and is collected in an adjacent tank. Then the filter is precoated again and the filtration restarted.

With the responses from the inquiries to the DE filter manufacturers and with the aid of a Johns-Manville Corp. representative, the following DE filter design criteria were developed for this application:

filter area	27.9 sq m (300.2 sq ft)
flow rate	607 to 757 lpm (160 to 200 gpm)
precoat	0.5 kg/sq m (0.10 lb/sq ft)
body feed	4 parts DE to 1 part suspended solids
DE required	Hyflow Super Cel
DE size	50% <11 μ

The filter selected was a Keene Model 610-E-328 pressure filter with a total surface area of 30.5 sq m (328 sq ft) with filtration elements consisting of polypropylene septum supports while the septum itself was a polypropylene cloth bag. This was the most economical filter of all those offered. The filter was sized to hold 0.52 cu m (18.5 cu ft) of filter cake. The filter was to be backwashed at a rate of 19 l/sec (300 gpm) with the Environmental Sciences Division designing the precoat and body feed tanks. Two 946 l (250 gal.) tanks were provided so that a precoat and body feed DE concentration of 40 to 60 gm/l could be maintained. The slurry was kept in suspension by a 1/3 hp, 1750 rpm Cleveland mixer. After precoating, both 946 l (250 gal.) tanks were to be utilized for body feed, whereas only one tank was needed for precoating. The filter was precoated by a Durco Mark II centrifugal pump rated at 568 l/m (150 gpm) at 18.3 m (60 ft) of head. The body feed was metered by a B.I.F. Industries Model 1731-30-0917 diaphragm metering pump with a right angle gear drive.

Figure 11 is a sketch of the final diatomaceous earth filtration system showing the plumbing between the different components of the system. The direction of flow of the precoat cycle, backwash cycle, and forward filtration are shown on the diagram. The filter backwash was directed into the heat exchange pit.

Design of Supporting Systems

The appurtenant equipment and tasks necessary to provide a functional demonstration system included site preparation, selection of the necessary flow metering equipment, and design of suitable electrical and pneumatic control systems. The site preparation included moving two washing machines from the treatment system area, providing concrete pads for the equipment, and filling in an existing water channel with concrete.

Bids for the erection, plumbing, and electrical work were obtained by laundry personnel.

The instrumentation includes two venturi flow meters with recorders and integrator totalizers to measure both inlet and outlet flow rates. It was hoped that the difference of these two measurements would be the scum volume generated each day. A flow through pH meter with strip chart recorder was also installed in the system to both measure and control effluent pH. The output of the pH meter went to a pneumatic

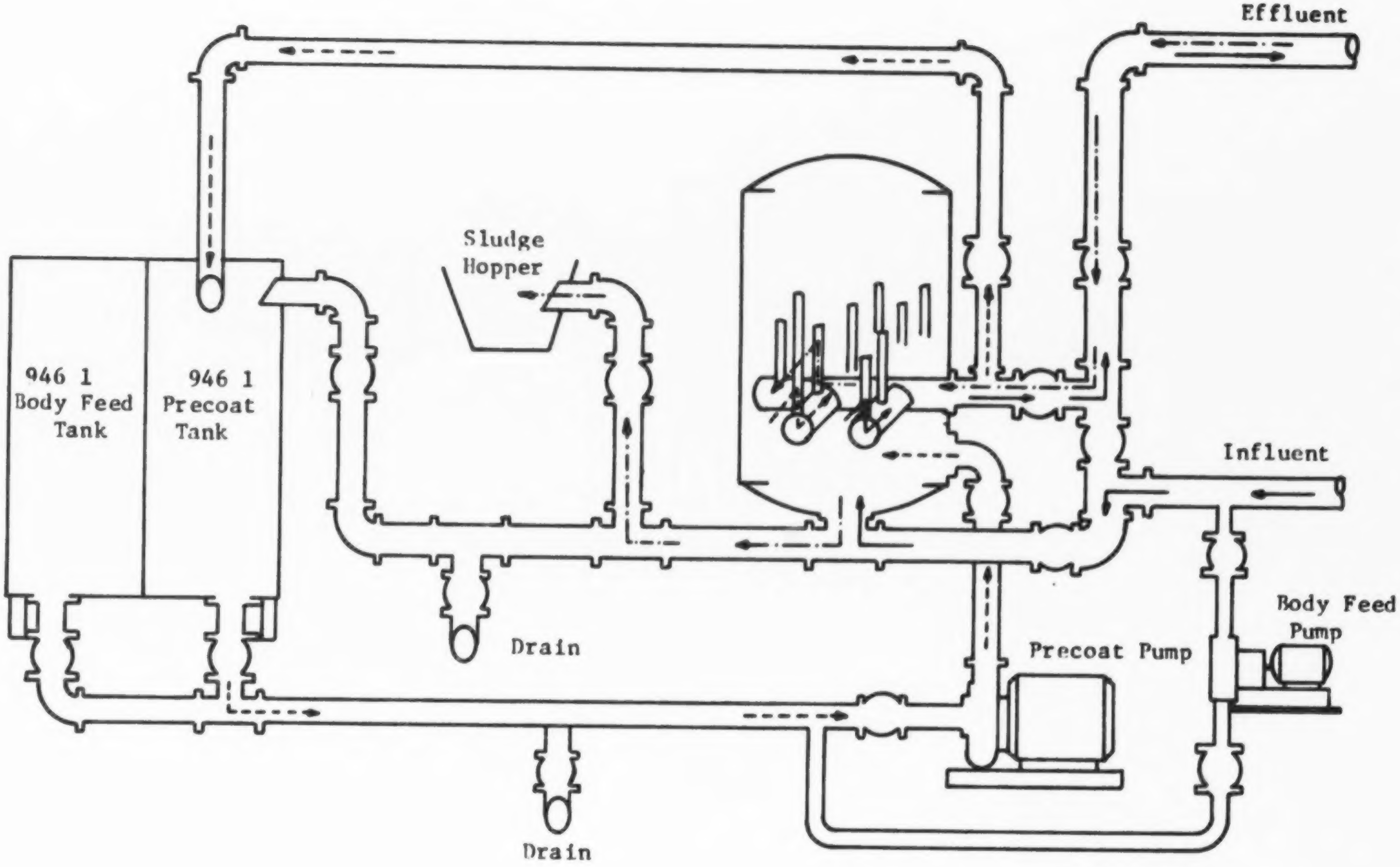

Effluent
Influent
Sludge Hopper
946 1 Body Feed Tank
946 1 Precoat Tank
Drain
Drain
Precoat Pump
Body Feed Pump
——— Raw Flow
- - - - - Precoat Flow
—·—·— Backwash Flow

FIGURE 11
DIATOMACEOUS EARTH FILTER SCHEMATIC DIAGRAM

transducer which converted the recorder's 4-20 milliamp signal to a 0.21 to 1.05 kg/sq cm (3 to 15 psi) air signal. This air pressure positioned a diaphragm valve on the discharge side of the acid feed pump. The air signal received was proportional to the difference in the desired pH (setpoint) and the measured pH. In this way, effluent pH would always meet the sewer code. Any excess acid pumped was recycled back into the acid container by bypassing the valve. An indicating mercury manometer connected to a sharp edged orifice plate measured pressurized flow. Various pressure gages were included in the air flotation system to keep track of the air solution process.

Figure 12 presents a process and instrumentation diagram for the system and shows all system controls. The untreated wastewater flow comes from the discharge side of the heat exchanger pump discharging to the sewer shown in the upper right hand corner of the diagram. The raw flow then goes to a rapid mix and flocculator chamber of the dimensions (1.8 x 1.8 x 3.4 meters (6 x 6 x 11 ft) deep. A movable baffle allows the detention time of each section to be varied. The raw flow to this process is recorded. Dissolved calcium chloride was added to either the pipeline or the rapid mix section of this tank and the polyelectrolyte to the flocculator section. Mixing and flocculation were achieved with either sparged air or three variable speed Cleveland mixers which could gently agitate the whole tank. The odd size of the chemical treatment facilities was also determined by the available floor area. Because of the shape of the flocculator tank, conventional turbine or paddle wheel flocculators could not be used. The tank was made extraordinarily deep in order to get the desired mixing time. It was felt the length of mixing for this particular wastewater was more important than the type of mixing, as laboratory testing had demonstrated that the floc was tough and not easily sheared. It also reformed readily. There was a total of 10 minutes detention time available in this tank.

From the flocculator, the chemically treated raw flow enters the flotation tank where solids separation occurs. The operation and control of this system was described previously. The flotation effluent then overflows a weir into a small storage tank, where it is either pumped to the sewer through the diatomaceous earth bypass or to the DE filter. An air operated weir type diaphragm valve on the discharge side of the diatomaceous earth pressurization or transfer pump was controlled by a bubbler level controller in the effluent storage tank. This was to insure that the transfer pump never ran dry and to control the flow to the DE filter. Theoretically, as the pressure drop built up in the DE filter, the flow to the filter would decrease causing a liquid level rise in the storage tank. The bubbler sensing this would cause the diaphragm valve to open wider to bring the level in the effluent storage tank down to the set point. The level controller was the same type used in the vacuum filter vat.

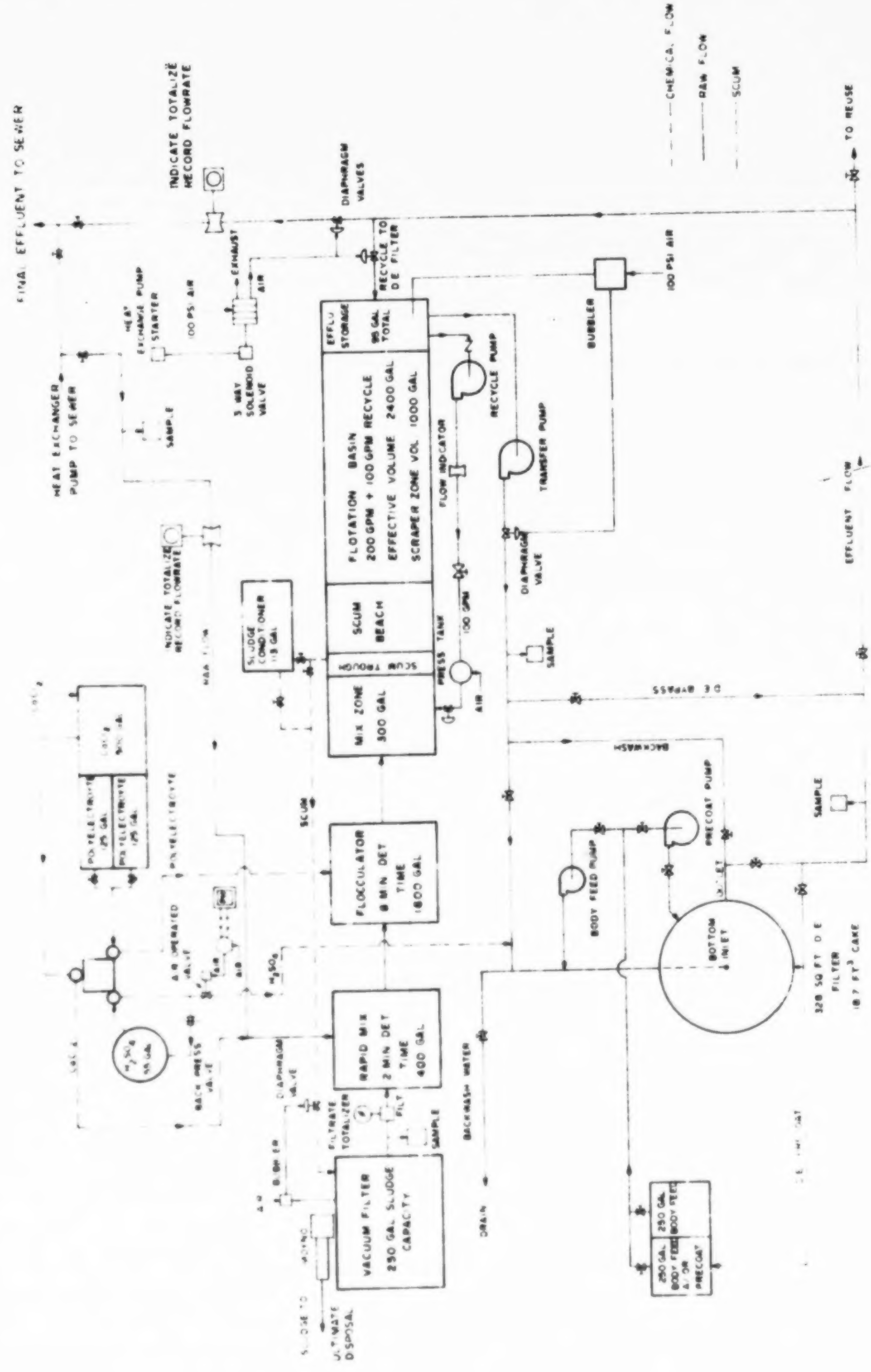

FINAL EFFLUENT TO SEWER
INDICATE TOTALIZE RECORD FLOWRATE
DIAPHRAGM VALVES
HEAT EXCHANGER PUMP TO SEWER
HEAT EXCHANGE PUMP STARTER
100 PSI AIR
SAMPLE
3 WAY SOLENOID VALVE
EXHAUST
AIR
RECYCLE TO D E FILTER
EFFLU STORAGE 95 GAL TOTAL
FLOTATION BASIN
200 GPM + 100 GPM RECYCLE
EFFECTIVE VOLUME 2400 GAL
SCRAPER ZONE VOL 1000 GAL
SCUM BEACH
SCUM TROUGH
MIX ZONE 300 GAL
SLUDGE CONDITIONER 115 GAL
FLOW INDICATOR
RECYCLE PUMP
TRANSFER PUMP
BUBBLER
100 PSI AIR
100 GPM
PRESS TANK
AIR
DIAPHRAGM VALVE
SAMPLE
D E BYPASS
BACKWASH
CHEMICAL FLOW
RAW FLOW
SCUM
TO REUSE
EFFLUENT FLOW
INDICATE TOTALIZE RECORD FLOWRATE
RAW FLOW
POLYELECTROLYTE 125 GAL
POLYELECTROLYTE 125 GAL
POLYELECTROLYTE
SCUM
FLOCCULATOR 8 MIN DET TIME 1600 GAL
AIR OPERATED VALVE
AIR
H_2SO_4
BACK PRESS VALVE
DIAPHRAGM VALVE
RAPID MIX 2 MIN DET TIME 400 GAL
FILTRATE TOTALIZER
FILT
SAMPLE
BLOWER
AIR
VACUUM FILTER 250 GAL SLUDGE CAPACITY
SLUDGE TO ULTIMATE DISPOSAL
BACKWASH WATER
DRAIN
BODY FEED PUMP
PRECOAT PUMP
OUTLET
BOTTOM INLET
SAMPLE
328 SQ FT D E FILTER 18.7 FT³ CAKE
250 GAL BODY FEED &/OR PRECOAT
250 GAL BODY FEED

FIGURE 12 PROCESS AND INSTRUMENTATION DIAGRAM FOR LAUNDRY WASTE TREATMENT SYSTEM

From the transfer pump, the flow could go to the DE filter, operated as described previously. A differential pressure sensor on the DE filter sounds an alarm when the setpoint is exceeded to indicate when backwashing is required. During a backwash the flow to the filter is reversed, and the transfer pump discharge used to backwash. The backwash water is directed to the heat exchanger pit. While the filter is being precoated again, the transfer pump discharge is directed to the DE bypass and to the sewer.

The heat exchanger pump feeding the system was controlled by a float switch in the heat exchanger pit. The demand for hot water in the laundry was also tied into this pump. At periods of low level in this pit or no heat demand (during lunch break) this pump would shut off. In order to prevent the wastewater treatment system from having to be shut down and started up frequently, whenever the pump shut off, two Grinnel diaphragm valves were actuated by a solenoid valve connected to plant air to redirect final effluent to the effluent storage tank. In this way, positive pressure was maintained on the DE filter to prevent cake loss and the pressurized flow was always kept running. When the pump started again, the flow was redirected to the sewer. When all motor starters and other switches were in the automatic position, this control scheme was in operation. Manual overrides were provided for all systems.

Two adjustable timers controlled the on time and the off time of the skimmers and bottom sludge scrapers. Automatic samplers were provided for the raw wastewater, vacuum filtrate, flotation effluent, and diatomaceous earth effluent. These were controlled by two adjustable timers such that the sampling interval and the length of sample could be controlled. The samplers were air driven valves, which opened when the first timer timed out and closed when the second timer timed out. In this way, true composite samples could be obtained from all four points. This sequencing was also stopped when the heat exchanger pump turned off.

The scum from the flotation unit was directed to the vacuum filter which operated as described previously. Vacuum level could be controlled by two butterfly valves on the pickup and dry vacuum lines. The scum could also be directed to a sludge conditioning tank with a side entering mixer and three minute detention time, if sludge conditioning should be required due to changes in sludge characteristics. Filtered sludge was pumped to a storage location outside the plant for ultimate disposal by a scavenging service.

The chemical feed system selected for this wastewater treatment installation consisted of two 473 l (125 gal.) polyelectrolyte tanks, one 1,892 l (500 gal.) calcium chloride tank, and a Chemcon triple headed metering chemical pump. Calcium chloride at a concentration of 500 gm/l of solution can be fed at rates of 0-4 lpm (0-1 gpm). The polyelectrolyte at a concentration of 0.2% can be fed at rates up to 1.0 lpm (¼ gpm) as can concentrated sulfuric acid. The acid was pumped from the drum in which it was supplied to the pH control system. Another double headed chemical metering pump was available for sludge conditioning if this should be required. All plumbing connections were made with 1.27 cm (0.5 in.) plastic tubing.

The design drawings for the system were completed in October of 1971. The tanks and system components were contracted for fabrication or ordered by mid-November of the same year. The contractors to perform the installation of the unit were selected by January of 1972 and all erection, plumbing and electrical work completed in April of that year. Costs for the demonstration system are presented in Appendix E.

OPERATIONAL METHODS AND TEST PLAN

The demonstration system was put into operation in May of 1972. The unit was to be tested to determine the effect of various process variables on effluent quality, as these related to local sewer ordinances. Variables requiring investigation are presented in Table 25. It was hoped that each of these variables could be run at several levels of operation so that their effect on effluent quality could be determined. It was desirable during the testing of the unit to firmly establish the following items for each type of laundry waste listed in Table 25:

operating costs
sludge volume production
optimum operating conditions
effect of laundry mix on treatment process

It was also part of the original EPA grant that the feasibility of reusing renovated wastewater in the laundering process be investigated. This was to be done by utilizing treatment system effluent directly in a 364 kg (800 lb) washing machine bringing it to the desired level on a batch basis for each washing operation. The water is then heated to the desired temperature with steam prior to commencing the laundering cycle. This is repeated for each wash operation. Samples of each dump are then taken to be compared to samples taken from each washing machine dump of a control batch of articles washed with softened city water. Laundry personnel then inspected each batch of washed items and evaluated their cleanliness. It was hoped that those laundering operations the wastewater effluent could be reused in could be identified as well as the rate of buildup of dissolved solids in the rinsed water. Likewise, it was hoped to determine if this dissolved solids buildup would have a detrimental effect on the wastewater treatment process.

During the evaluation of the system, it was to be operated four days per week at the specified overflow rate, chemical dosage, and other variable levels. Composite samples of influent, flotation effluent, and vacuum filtrate were taken automatically and analyzed for the constituents

TABLE 25

PROCESS VARIABLES TO BE INVESTIGATED FOR LAUNDRY WASTEWATER TREATMENT

Laundry Mix

- Industrial - wipers, dust mops
- Uniforms - shirts, pants, coveralls
- Linens - tablecloths, towels, etc.
- Diapers

Chemical Treatment

- Dosage
- Point of addition
- Flocculation time
- Rapid mix time

Flotation

- Overflow rate
- Skimming Cycle
- Pressurized Flow

Diatomaceous Earth Filtration

- DE grade
- Body feed rate
- Hydraulic Loading
- Pressure buildup - length of filter run

Vacuum Filtration

- Pick-up time
- Cycle time
- Vacuum level

listed in Table 26 at the interval specified. The vacuum filtrate samples would have only solids analyses performed on them. Grab samples of scum were composited manually. Grab samples of any process stream were taken during any system upset or unusual condition and analyzed for those constituents deemed important.

The vacuum filter was sampled manually with a sharp edged circular cutter of approximately 0.0093 sq m (0.1 sq ft) area. Normally 3 cake samples of this size were taken at both ends and the center of the drum to equalize the variation in cake solids and thickness normally found across the filter drum. Several samples of this type were taken at regular intervals and averaged to represent the response variable values at a particular set of operating conditions. Following any change in operating conditions, at least 5 drum revolutions were allowed to occur before any cake samples were taken as representative of those operating conditions. After sampling, the cake was placed in an aluminum tin and weighed immediately.

The vacuum filter was operated so that it would just keep pace with the sludge production of the flotation system, so that the filter could be operated continuously. A vacuum filter is generally not amenable to sporadic operation. Due to our limited sludge storage, sludge had to be filtered almost as soon as it was produced.

No rigid test schedule was followed so that when unanticipated important parameters manifested themselves, they could be properly investigated. Likewise, the nature and variability of the wastewater made it evident that certain operating conditions would have to be developed during the progress of the project as experience with the treatment system was gained. Thus it was felt that this test plan would accomplish the project objectives set out at the beginning of this report.

It was desirable to test the four different types of laundry wastewater listed in Table 25 because of the very different characteristics of all four wastewaters and because each one made up a significant portion of the laundry industry in general. It was felt that if the treatment system was designed for the strongest, and presumably the most difficult to treat wastewater, it would be flexible enough to handle linen, diaper, and uniform laundry wastewater which would be expected to be weaker. These other wastewaters and the bench scale test work and design decisions associated with them are presented later in this report.

TABLE 26

LAUNDRY WASTEWATER ANALYSES TO BE PERFORMED ON COMPOSITE SAMPLES

Parameter	Analysis Interval
BOD	weekly
TOC	daily
Hexane Solubles	daily
pH	daily
Suspended and Volatile Suspended Solids	daily
Total and Volatile Total Solids	daily
Alkalinity	daily
Calcium	weekly
Lead	weekly
Mercury	weekly
Cadmium	weekly
Zinc	weekly
Copper	weekly
Chromium	weekly
Iron	weekly
Nickel	weekly
Silica	weekly

SECTION V

INDUSTRIAL LAUNDRY WASTEWATER TREATMENT SYSTEM OPERATION

INITIAL OPERATION AND DEBUGGING

The operation of the system was initially delayed due to the lack of a permit from the City of Chicago to construct a sludge discharge line from the laundry over an alley to the sludge dumpster site. Until this permit could be received, it was not possible to operate the treatment unit and remove sludge from the system, making evaluation of the operation fruitless.

During this time period, the system was operated wet with the scum generated being drained to the heat exchanger pit, so that mechanical malfunctions or process problems could be resolved prior to actual system operation. Some of the problems that were corrected during this time period are listed below.

Improper motor heater sizes on all motors
Misalignment of skimmer sprocket and chains
Additional skimmers added
Replacement of bolts in bottom scrapers
Plumbing modification to vacuum filter
Moved effluent flow meter

After performing the above tasks and many other minor ones, the system was operated utilizing one cubic yard carts to collect the vacuum filtered sludge. The unit could only be operated for short periods of time in this manner due to the large quantities of sludge generated. Six runs were performed in this manner to evaluate initial treatment results and to further debug the wastewater treatment system. Wastewater samples were obtained from four of the runs. Table 27 presents the basic operating conditions for these four runs, while Table 28 reflects the performance of the vacuum filter and Table 29 presents the wastewater analyses performed on the composite samples obtained. The length of operation was limited by the volume of sludge that could be processed.

It can be seen that the vacuum filter results varied significantly even while operating at the same conditions. Cake solids varied between 10% and 22%. Likewise, filter yield also fluctuated significantly. Some of this variability in solids could be due to volatilization of some greases

TABLE 27

SYSTEM OPERATING CONDITIONS

FOR RUNS OF JULY AND AUGUST, 1972

Parameter	8/8 Run 1	8/8 Run 2	8/9	7/19
Length of Run, hours	1.5	1.5	2.9	3.25
$CaCl_2$ Dosage, mg/l	1860	1300	1660	1170
A-23 Dosage, mg/l	1.8	1.2	1.3	0.9
Recycle Ratio, %	80	56	59	57
Raw Flow, lpm	473	681	643	662
Overflow Rate, lpm/sq m	85.5	105.8	101.7	105.8
Vacuum Filter Cycle Time, min.	3.25	3.25	--	3-5.7
Vacuum Level, cm Hg.	50.8	50.8	--	38.1-45.7
Avg. Pick Up Time, sec.	40	40	--	--
Sludge Flow Rate, lpm	15	15	--	12.5
DE Filter Pressure Buildup, kg/sq cm/hr	--	--	0.5	
DE Body Feed, mg/l	--	--	200	
DE Grade			Hyflow Super Cell	

TABLE 28

RESULTS OF VACUUM FILTER

OPERATION OF JULY AND AUGUST, 1972

Date	Vacuum Level (cm Hg)	Pickup Time (sec)	Cycle Time (min)	Solids Loading (kg/sq m)	Yield (kg/sq m/hr)	Cake Solids Percent
7/13	25.4-50.8	--	3.25	0.622	11.52	14.02
7/13	25.4-50.8	--	3.25	0.622	11.47	21.90
7/18	50.8-63.5	--	5.7	1.681	17.64	18.62
7/19	38.1-45.7	--	3.0	0.676	13.57	14.85
7/19	38.1-45.7	--	3.0	0.730	14.55	15.18
7/19	38.1-45.7	--	5.7	1.480	15.53	16.60
7/19	38.1-45.7	--	5.7	1.078	11.32	12.61
8/8	50.8	40	3.25	1.152	21.22	10.12
8/8	50.8	40	3.25	1.176	21.71	18.76
8/8	50.8	40	3.25	0.990	18.33	14.01
8/8	50.8	40	3.25	0.936	17.30	12.79
8/8	50.8	51	4.16	0.862	12.40	20.65

TABLE 29
INITIAL INDUSTRIAL WASTEWATER TREATMENT RESULTS

Analysis	Raw Wastewater				Flotation Effluent				DE Eff.	System % Removal			
	7/19	8/8-1	8/8-2	8/9	7/19	8/8-1	8/8-2	8/9	8/19	7/19	8/8-1	8/8-2	8/9
pH - units	12.2	11.8	11.8	11.85	12.15	11.6	11.5	11.5	11.45	--	--	--	--
Total Solids, mg/l	6469	5042	5042	8649	4117	3704	3369	5694	5609	36.4	26.5	33.2	35.1
Suspended Solids, mg/l	1870	2096	2096	4950	385	99	112	108	9	79.4	95.3	94.7	99.8
TOC, mg/l	4150	3200	3200	6300	700	490	620	440	320	83.1	84.7	80.6	94.9
Hexane Solubles, mg/l	5319	2121	2121	2805	215	23	60	146	17	96.0	97.1	98.9	99.4
Silica, mg/l				230				7	8				97.0
Mercury, μg/l				1.2				<0.5	<0.5				58.3
Zinc, mg/l				8.88				0.35	0.18				98.0
Nickel, mg/l				1.0				0.30	0.20				80.0
Lead, mg/l				35.8				0.35	0.10				99.7
Chromium, mg/l				3.60				3.25	3.86				0
Cadmium, mg/l				0.60				0.03	0.03				95.0
Copper, mg/l				9.3				0.69	0.50				93.4
Iron, mg/l				126				2.4	2.4				9.81

and oils when drying in the oven at 102°C. Likewise, since there is no sludge blending or storage time available in the unit, the solids concentration of the scum varied significantly with time. Scum solids concentrations of 3.3% to 9.0% were demonstrated on two of the days, and this contributes to changing vacuum filter performance.

The initial vacuum filter yield, i.e., the kilograms of dry sludge solids filtered on one square meter of cloth in one hour, was not as high as hoped for. The cake solids obtained were about what was expected. The solids loading presented in Table 28 is the mass of dry sludge solids filtered per square meter of filter area, whereas the cycle time is the length of time required for one drum revolution. Filter yield is calculated by multiplying the solids loading by 60 over the cycle time. The moisture content of the sludge is calculated as 100% minus the cake solids. It may be noted that filter yields of only 12 to 20 kgs/sq m/hr (3 to 4 lbs/sq ft/hr) were obtained as against projected yields of 24 to 29 kg/sq m/hr (5 to 6 lb/sq ft/hr). The filter manifested no blinding problems duirng these operations, and demonstrated that it was debugged.

The nature of the sludge caused difficulties in the sludge handling facilities. After the sludge had been pumped by the Moyno cake pump, it liquified. This made the sludge a liquid disposal problem, and as such could not be handled in an open topped dumpster by an ordinary scavenger. Since the sludge was a liquid, it could not be legally landfilled as a solid waste. Consequently, haulers specializing in the disposal of liquid wastes had to become the regular handlers of the wastewater treatment residue. This caused a considerable increase in hauling cost; $11.75/cu m ($9.00/cubic yard - cu yd) versus $3.20 cu m ($2.50 cu yd). All sludge generated for the rest of this project was handled as a liquid waste. The location of the laundry on the western side of Chicago limited the alternatives for sludge handling at this site.

Table 29 demonstrates that the flotation unit was doing its job in removing grease and solids as well as a good deal of organic matter. The effluent quality obtained from these samples was excellent considering the raw wastewater characteristics. It was not anticipated that the results would be as good as the bench scale testing, due to the batch nature of this type of test. The flotation tank produced an acceptable effluent operating near the design conditions during these four runs, notably 1,500 mg/1 of calcium chloride and a raw flow of 644 to 682 lpm (170-180 gpm). Wastewater variation in characteristics did not appear to adversely affect the chemical treatment.

The diatomaceous earth filter operation of August 9 was highly promising, as the DE filter built up little pressure drop during the run indicating the DE filter might need little DE to do an effective treatment job. The clarity of the DE effluent was excellent as attested to by the 9 mg/1 suspended solids in the effluent. It is apparent the DE filter was an excellent polishing step, and that it removed a residual of heavy metals.

Table 29 lists the results of the August 9 heavy metals analyses and the percentage removal of each contaminant. From this table, it is evident that the treatment system was removing all contaminants under consideration except for chromium. Evidently, no chromium was removed because it was present in the hexavalent form. In order for chromium to be removed at a high pH, it must be reduced to the trivalent form to be precipatated as a hydroxide. The heavy metal removal demonstrated in the laboratory was duplicated in the field.

Thus the initial operation of the industrial laundry wastewater treatment system was very promising. Based on these results, it was felt that the debugging of the system was completed.

WASTEWATER TREATMENT SYSTEM OPTIMIZATION

The permit for the sludge carrying pipe was received in August of 1972, so that the sludge handling facilities were ready for full time operation in September of that year. The open topped dumpster was replaced at this time with a liquid tanker. The completion of this part of the system allowed the actual test plan to commence. The first test was performed on October 11, 1972 with the first full week of operation occurring during the week of October 15. The basic operating parameter for these runs are presented in Table 30. During these runs, the DE filter was utilized only once.

Irrespective of the test conditions, it is apparent that the operation of the flotation unit was unsatisfactory on all test days in terms of effluent suspended solids and hexane solubles, as shown in Table 31. Of all the test runs, the one at the lowest overflow rate provided the best results. However, in no case were the effluent suspended solids, TOC, or hexane solubles approaching the concentrations obtained in the bench scale testing or the preliminary operation. Neither overflow rate or chemical dosage appeared to affect the solids separation - an inconsistent result.

A severe vacuum filter cloth blinding problem now manifested itself also. During the October 17 and 18 operations, filter blinding was a definite problem. At times the filter cloth would produce a cake one half inch thick and then suddenly not produce a cake thick enough to discharge. When this occurs, the filter must be shut down and the cloth manually cleaned, and if the problem is not rectified, the whole treatment system must be shut down in order to get rid of the scum. It thus appeared that some substance was coming through periodically causing poor filtration, then disappearing and the filter recovering. Filter cake solids of 27% to 54% were obtained with filter yields varying from 11.3 to 34.3 kgs/sq m/hr (2.3 to 7.0 lbs. dry solids/sq ft/hr). The scum total solids concentrations were somewhat variable, but were generally near 5%. Some scum samples that caused blinding contained 7.6% solids - a more than adequate concentration to provide a thick cake. The scum concentration did not correlate well with filter yield as it should have; as according to filtration theory, the higher the solids concentration, the higher the filter yield (11). Therefore, the filter blinding was not related to inadequate scum solids concentration.

TABLE 30

SYSTEM OPERATING CONDITIONS FOR OCTOBER 11 TO OCTOBER 20, 1972

Parameter	10/11	10/17	10/18	10/19	10/20
Length of Run - hours	5.0	3.8	3.0	5.1	4.3
Avg. Raw Flow Rate - lpm	568	719	814	341	795
% Recycle	80	53	46	111	48
$CaCl_2$ Dosage - mg/l	2,100	1,550	--	1,355	2,040
A-23 Dosage - mg/l	1.5	0.9	0.5	1.3	0.5
Skimmer Speed - mpm*	0.60	0.46	0.46	0.46	0.46
Overflow Rate - lpm/sq m	102	110	118	73	118

* 5 minutes on and 5 minutes off.

TABLE 31

WASTEWATER QUALITY FOR FIVE TEST DAYS
BETWEEN OCTOBER 11 AND OCTOBER 20, 1972

Analysis	Operating Date				
	10/11	10/17	10/18	10/19	10/20
Raw Wastewater					
Total Solids - mg/l	6,068	4,230	6,217	5,996	6,662
Suspended Solids - mg/l	--	2,825	3,965	3,620	3,775
TOC - mg/l	--	3,200	3,120	3,260	4,200
Hexane Solubles - mg/l	--	2,600	3,363	3,418	3,756
pH - units	12.0	10.0	11.5	11.65	11.7
Silica - mg/l as SiO_2	--	690	810	670	830
Flotation Effluent:					
Total Solids - mg/l	4,541	3,891	4,736	5,033	6,670
Suspended Solids - mg/l	908	1,058	1,991	782	2,914
TOC - mg/l	--	980	1,360	920	1,740
Hexane Solubles - mg/l	502	566	1,006	425	1,663
pH - units	11.4	9.9	10.6	11.6	10.9
Silica - mg/l as SiO_2	--	55	72	16	43
Scum Concentration					
Average Total Solids - %	6.9	1.7	8.6	8.4	5.2
Grease - % of Solids	--	56	76	53	--
DE Filter Effluent:					
Total Solids - mg/l					2,876
Suspended Solids - mg/l					48
TOC - mg/l					123
Hexane Solubles - mg/l					16
pH units					10.65
Silica - mg/l as SiO_2					108

During the October 20 operation, a complete series of heavy metal analyses were performed to determine if these contaminants were still being removed by the treatment system in view of its poor performance. Table 32 provides this data, and indicates a quite favorable DE effluent quality in terms of heavy metals, in spite of the poor flotation effluent. The very high suspended solids concentration of the flotation effluent shortened the DE filter run considerably (0.5 hrs), but demonstrated that the DE filter could produce very high effluent quality, even under adverse conditions. Thus the DE filter could be expected to cover up system upsets for short periods of time. However, better quality flotation effluent was obviously required if DE usage was to be kept at a reasonable cost. The high removal percentages of the heavy metals indicated that they were still in a form amenable to solids separation, in spite of the deterioration in the wastewater treatment system performance.

Analysis of grab samples of the various waste streams from the October 11 run demonstrated that the performance of the flotation process was erratic even at the same operating conditions. This is aptly demonstrated by Figure 13. This did not appear to be a function of raw wastewater solids concentration, as shown in Figure 13. Because of the erratic and inefficient operation of the flotation unit, and the blinding of the vacuum filter, work was halted to evaluate these problems. Until the root cause of the filtration blinding problem was identified, no meaningful treatment system performance data could be obtained.

Problem Identification

While evaluating the above problems, it appeared that there might have been a change in the washing mix since the time the bench scale tests were first performed in March of 1971. The basic change appeared to be in the percentage of printer's towels now making up the wash load. Table 33 presents all the data available on this information at this time. The general wash mix had not been extensively recorded up to this time, and the laundry did not keep these records for long periods. It is evident that the print wiper percentage was considerably greater during the October 17, 1972 operation of the treatment system. It is not known if this was due to an actual increase in the laundry's print wiper trade or merely indicative of a large amount of variability in the proportion of printer's towels washed that was not reflected in the initial sampling program. The extent of the filter blinding problem, which had not manifested itself before, suggested that some basic change had indeed occurred.

Because of this observation, on November 10, 1972 the system was operated while print wipers and machine wipers were laundered at different times. From 7:30 am until 11:00 am, only printer's towels were laundered in the industrial washing machines. From 11:00 am to 1:15 pm, only shop towels were laundered in these same washing machines. The laundry maintained its normal linen and dust mop wash schedule throughout the day. At 1:15 pm, the laundry again began washing printer's towels.

TABLE 32

REMOVAL OF HEAVY METAL CONTAMINANTS BY THE INDUSTRIAL LAUNDRY WASTEWATER TREATMENT SYSTEM ON OCTOBER 20, 1972

Analysis	Raw Wastewater	DE Effluent	% Removal
Zinc - mg/l	6.8	0.06	99.1
Chromium - mg/l	2.25	0.26	88.4
Lead - mg/l	16.5	0.20	98.8
Copper - mg/l	6.1	0.20	96.7
Cadmium - mg/l	0.45	0.1	77.8
Iron - mg/l	67	0.2	99.7
Nickel - mg/l	1	1	0

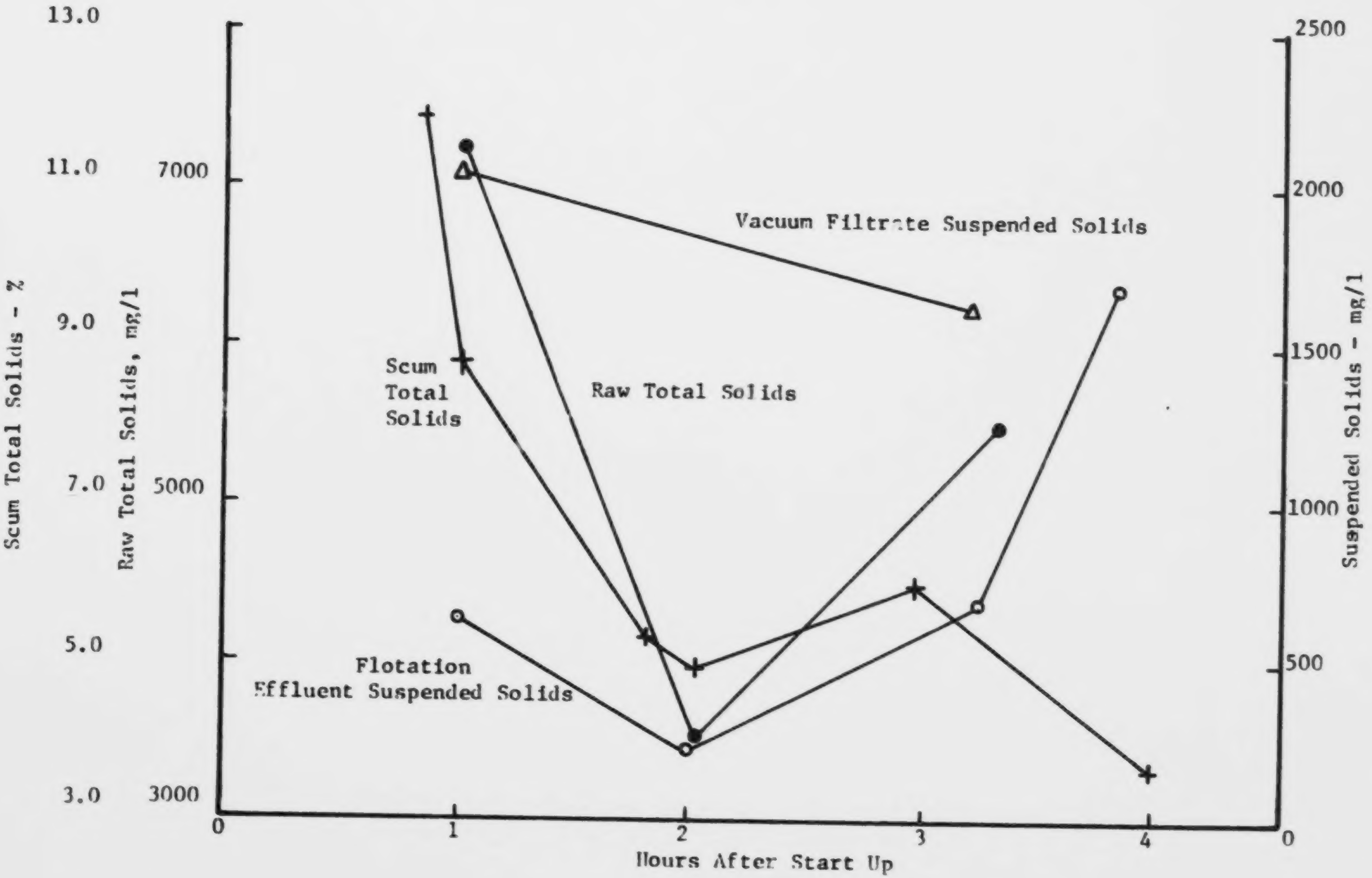


FIGURE 13

VARIATION OF TREATMENT SYSTEM SOLIDS WITH TIME ON OCTOBER 11, 1972

TABLE 33

PROPORTIONS OF PRINTER'S TOWELS IN THE TOTAL LAUNDRY WASH VOLUME

Date	Percentage Printer's Towels in Total Wash Volume
3/3/71	0
3/15/71	17
5/19/71	25
5/20/71	29
10/17/72	42

During this testing, the flotation system was operated at a flow rate of 567 lpm (150 gpm) and 67% recycle. The calcium chloride dosage was 2,200 mg/l and the A-23 polyelectrolyte dosage was 2.3 mg/l. The vacuum filter was operated at a cycle time of 4 to 5.5 minutes at a 15.2 cm (6 in.) submergence and vacuum levels of 25.4 to 63.5 cm Hg. Grab samples of raw flow, scum, and flotation effluent were obtained every 15 minutes. Buchner funnel tests were performed side by side with the vacuum filter using different cloth media to determine if a different filter cloth would overcome the blinding problem.

Figures 14 and 15 present the variation of influent and effluent wastewater quality during the test day. The time periods when the laundering of each item occurred are clearly marked. There were large variations in wastewater quality for both print wipers and machine wipers. However, the figures show no readily discernible differences in wastewater quality for either of the two items. Consequently, the data presented in Figures 14 and 15 for the various grab samples were averaged for comparative purposes. The results are shown in Table 34, and two apparent differences between print wiper and machine wiper wastewater which manifest themselves are in the areas of TOC and grease. The print wiper wastewater has a somewhat higher grease and TOC content than the machine wiper wastewater. Scum samples also indicated a higher suspended solids content for the scum generated by the machine wipers than that generated by the print wipers. This would indicate that print wipers produce a smaller amount of filterable solids than machine wipers, and that the print wipers contain more organic material than the machine wipers. These samples did not demonstrate any dramatic differences in wastewater characteristics that would account for any difference in sludge filterability.

During this test, the print wiper scum never was in a filterable condition. The vacuum filter blinded immediately and discharged for a period of only 0.5 hours out of the 3.5 hours available during the print wiper laundering. After the print wiper testing, the print wiper scum was all skimmed from the flotation unit and allowed to drain from the system prior to sampling for the machine wiper wastewater. At 11:00 (200 minutes) when the waste treatment operation was converted over to machine wiper wastewater, the scum was immediately dewaterable. At 1:15 (335 minutes), when print wipers were again being washed, the filter blinding again manifested itself.

The Buchner funnel tests performed with various cloth types side by side with the vacuum filter failed to provide any filter cloths that did not blind. Even relatively open meshed branched monofilament polypropylene cloths with air permeabilities of 17 to 42.5 cu m/sq m (200 to 500 cfm/sq ft) blinded quickly on the print wiper scum. Neither open mesh monofilament or multifilament cloths of various characteristics could filter the print wiper scum properly. This demonstrated that the filter blinding was not a characteristics of the filter cloth, but of the print wiper sludge since this sludge would not filter well on any filtration media tested.

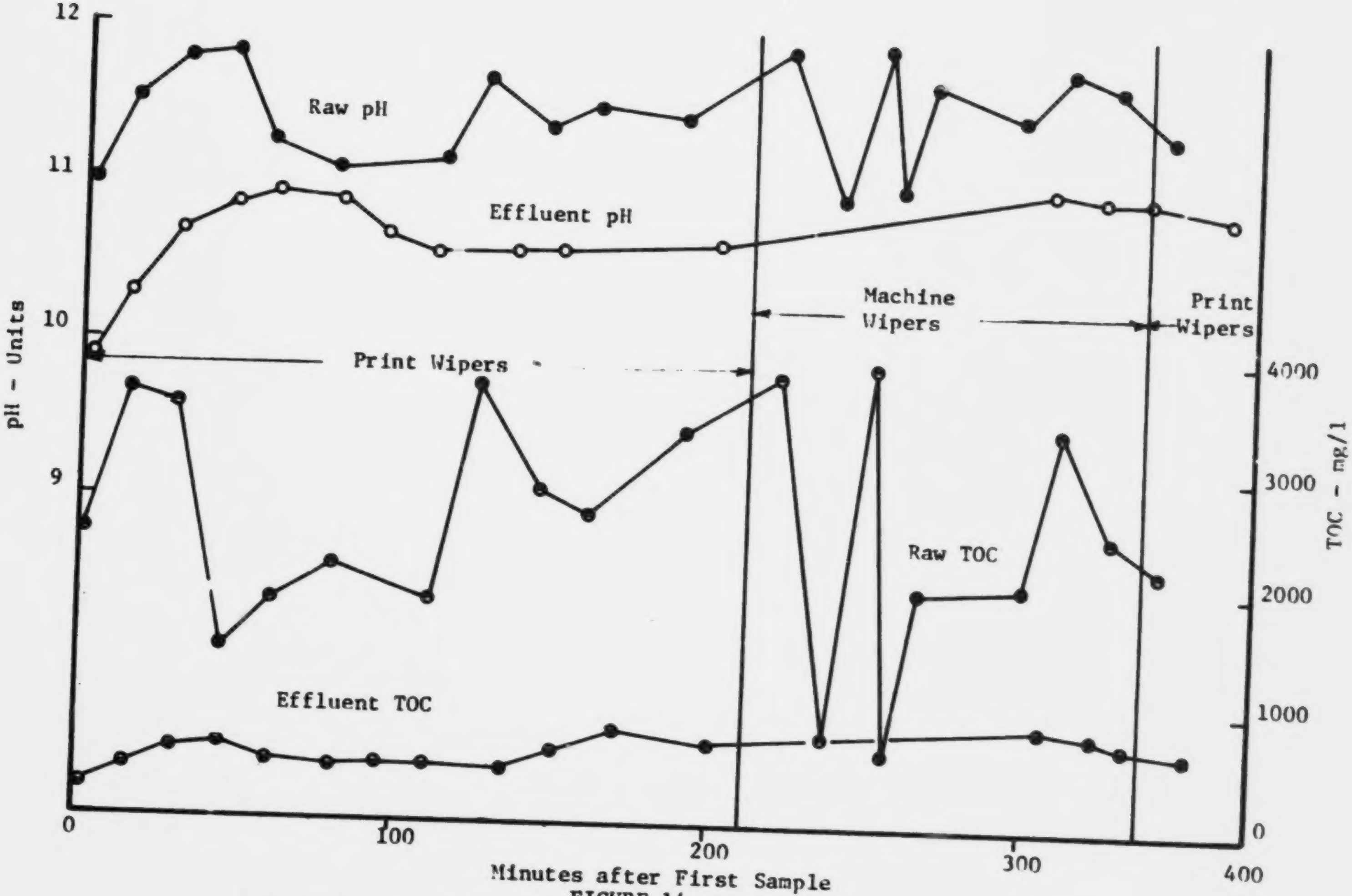


FIGURE 14
VARIATION OF RAW AND EFFLUENT WASTEWATER pH and TOC WITH TIME FOR NOVEMBER 10, 1972 WASTEWATER TREATMENT SYSTEM OPERATION

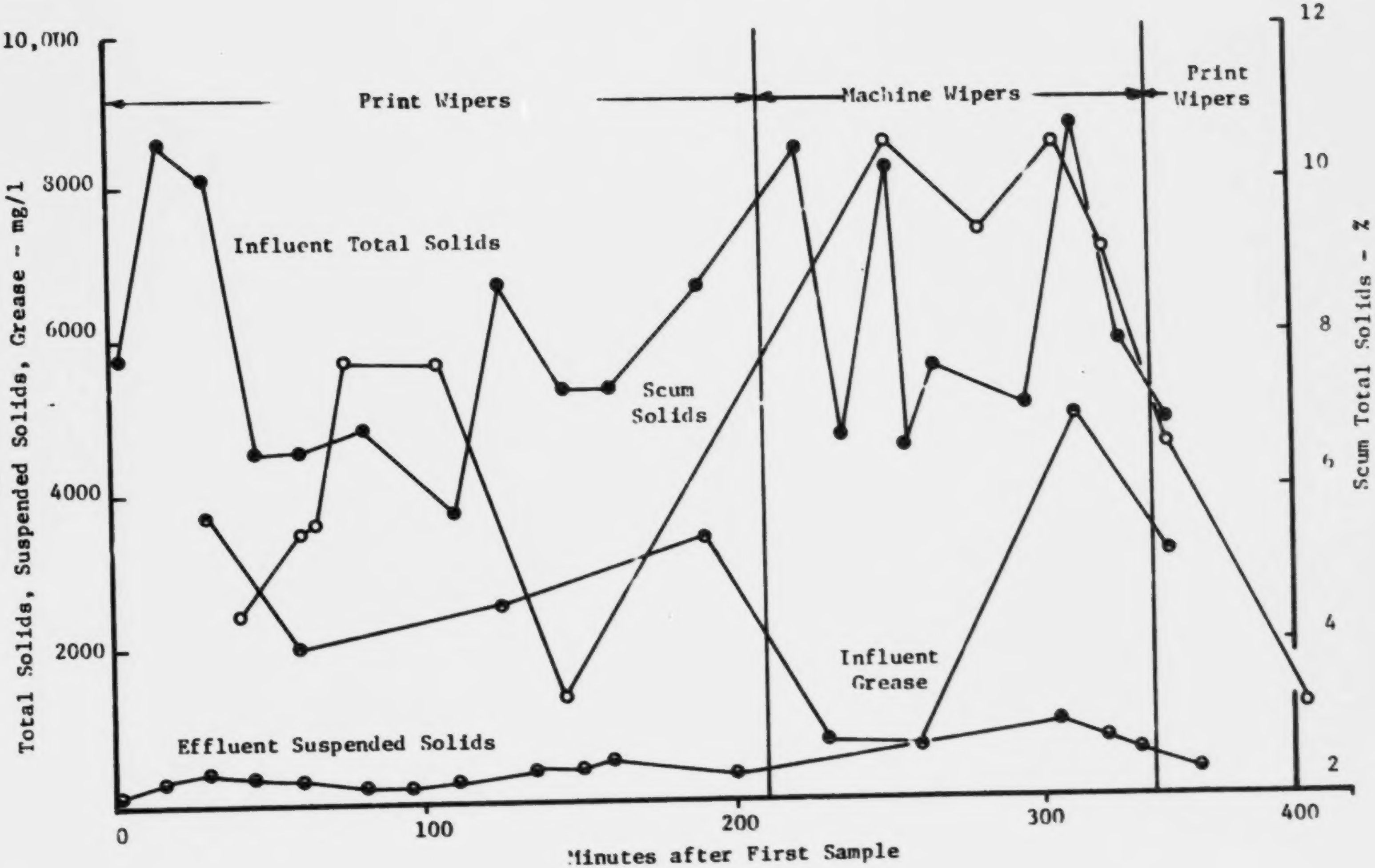


FIGURE 15
VARIATION OF SEVERAL WASTEWATER CHARACTERISTICS WITH TIME FOR NOVEMBER 10, 1972 WASTEWATER TREATMENT SYSTEM OPERATION

TABLE 34

AVERAGE CHARACTERISTICS OF PRINT AND MACHINE WIPER WASTEWATER

FOR NOVEMBER 10, 1972

Parameter	Print Wipers	Machine Wiper
Raw TOC, mg/l	2,758	2,175
Effluent TOC, mg/l	536	760
Raw Grease, mg/l	2,932	2,379
Effluent Grease, mg/l	832	1,112
Effluent Suspended Solids, mg/l	309	654
Scum Total Solids, %	8.05	8.98
Raw Total Solids, mg/l	6,048	5,964
Raw Volatile Total Solids, %	55.4	51.4
Effluent Suspended Volatile Solids, %	50.0	65.9
Scum Volatile Total Solids, %	67.4	68.4
Scum Suspended Solids, %	6.47	9.15
Scum Volatile Suspended Solids, %*	67.2	70.4

* Not run on all samples.

Consequently, sludge samples of machine wiper and print wiper scum were brought back to the laboratory for further testing. The sludge concentrations of these samples are presented in Table 35. The scum samples obtained were then Buchner funnel tested to determine if there were sludge conditioning methods that would increase the sludge filtration rate. Buchner funnel testing was performed using a 9 cm funnel at a vacuum of 63.5 cm Hg to 68.6 cm Hg with a volume of 150 ml of sludge and No. 541 Whatman filter paper in all cases. With no modification in sludge characteristics, the machine wiper sludge would yield 100 ml of filtrate in 10 seconds while print wiper sludge provided 100 ml of filtrate in 240 seconds. Thus the difference in sludge filterability was evident.

Various polyelectrolytes were used in sludge conditioning tests to determine if this would improve the filtration rate of print wiper sludge. Comparisons were made on the basis of filtration rate (sec/volume) rather than specific resistance to facilitate more rapid testing.

Cationic and anionic polyelectrolytes utilized at different sludge pH's, and in combination with ferric chloride, lime, and other metal salts failed to improve print wiper sludge filterability. However, it was found during these studies that pH adjustment of the sludge resulted in increased filtration rates. Therefore, a series of experiments were performed to determine sludge filtration rates at various pH values. This was done for print wiper scum, machine wiper scum, and a blend of one half of each of the scums by volume. Figure 16 presents these results where the ordinate of Figure 16 is the time required to collect 75 ml of filtrate during this test. It is evident from this figure that decreasing pH resulted in increased filtration rates for all three sludges. The optimum pH was found to be near 3.0.

Because of the good vacuum filtration dewatering characteristics of machine wiper sludge, various blends of print wiper and machine wiper sludges were filtered in the same manner as the previous testing. Figure 17 demonstrates that the combined sludge filtration rate decreases at an increasing rate as more and more print wiper scum is added. This figure indicates the need for sludge equalization. Due to the difficulty of doing this at this laundry, equalization of the raw waste could be used to accomplish the same result. This would help prevent slugs of material emanating from the print wipers from reaching the vacuum filter.

Some of the print wiper scum was centrifuged in order to separate the oily fraction from the solids. Buchner funnel testing of these solids also demonstrated filter blinding properties. Filter blinding was then not associated with the oily material.

It is common knowledge that metallic hydroxides do not filter well due to their gelatinous nature (15). Consequently, both the machine and print wiper scums were analyzed for heavy metals. Table 36 shows that there were more heavy metals in the machine wiper scum than the print wiper scum. The machine wiper scum filtered better than the print wiper scum, thus tending to rule out the hypothesis that metallic hydroxides were

TABLE 35

CHEMICAL CHARACTERISTICS OF SCUMS USED IN LABORATORY TESTING

Analysis	Machine Wiper Scum	Print Wiper Scum
Total Solids - %	10.7	8.8
Volatile Total Solids - %	7.2	6.9
Suspended Solids - %	9.2	3.5
Volatile Suspended Solids	6.0	2.1
Grease - %	7.4	4.3

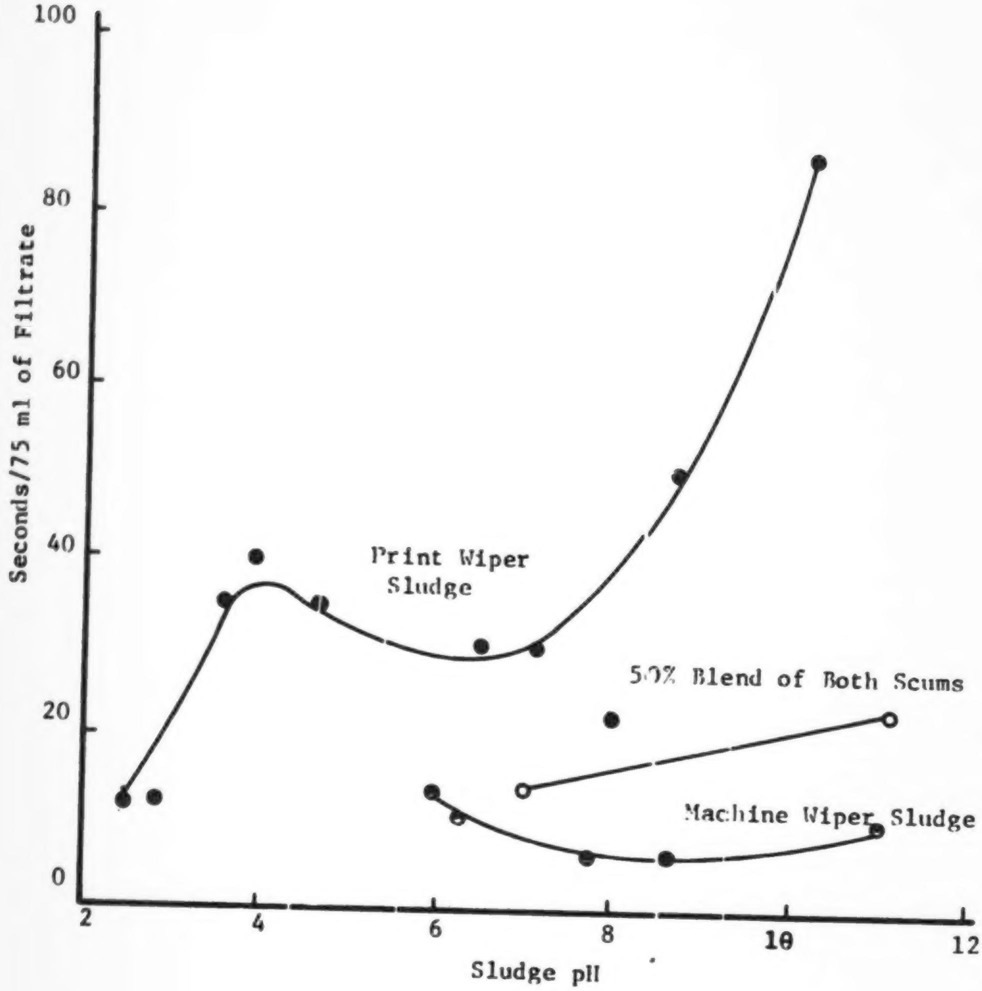


FIGURE 16

EFFECT OF SLUDGE pH ON FILTERABILITY
FOR THREE DIFFERENT MIXES OF LAUNDRY WASTEWATER

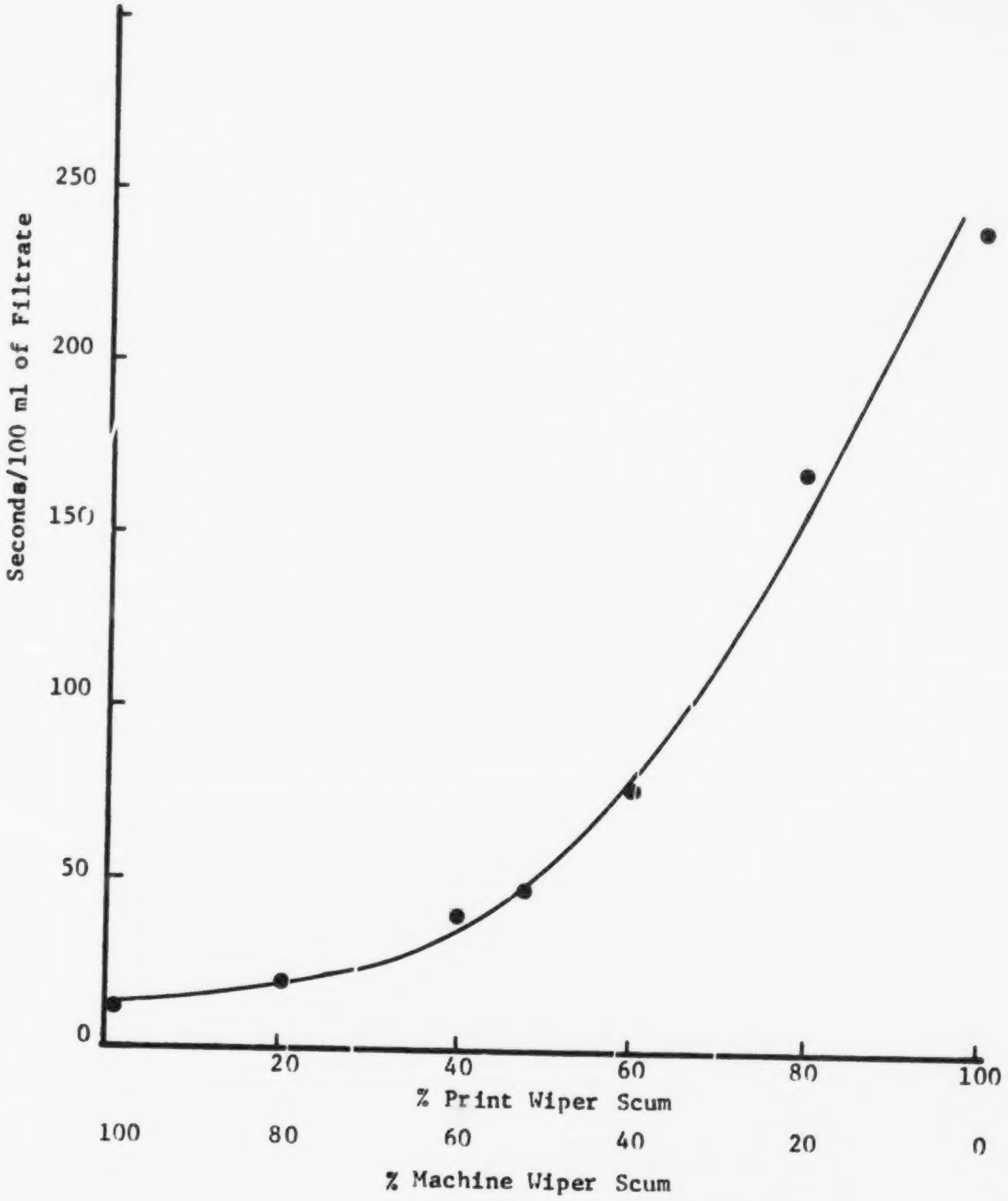


FIGURE 17

EFFECT OF VARIOUS RATIOS OF PRINT WIPER SCUM AND MACHINE WIPER SCUM ON SCUM FILTERABILITY

TABLE 36

HEAVY METAL CONTENT
OF TWO LAUNDRY FLOTATION SCUMS

Item	Machine Wiper Sludge	Print Wiper Sludge
Lead - mg/l	261	162
Copper - mg/l	48	31
Zinc - mg/l	89	41
Iron - mg/l	818	199

the problem. However, there can be two types of metal present in the wipers. Chips of lead and iron can be present in both types of wipers, and would be measured in the heavy metal analyses. Likewise, some metallic ions would be dissolved and would be precipitated as hydroxides by the caustic of the wash formula. A particular metal can then be present as its hydroxide or its un-ionized form. The metal chips would of course filter quite well, whereas the metallic hydroxides would not. Because no distinction could be made between the two forms of metal for the two samples, the results of the testing were inconclusive. An attempt to use heavy metal analysis of filtered acidified scum filtrate as a measure of metallic hydroxides, i.e., assuming that metallic hydroxides would dissolve quickly in acid and particulate metals would not, also failed to show any significant differences between the two sludges.

Thus it was determined that the characteristics of the solids associated with the print wiper wash water were the cause of the filter blinding problems. An effort to identify the nature of the solids causing this problem met with no success. Based on these results, it was concluded that raw wastewater equalization was required, and that sludge neutralization would increase the filtration rate. This led to replumbing of the treatment system so that the linen storage pit could be used for equalization and sulfuric acid could be fed into the sludge conditioning tank. The equalization basin was mixed with air diffusers.

On December 20 a two hour run of the treatment system utilizing sludge neutralization was performed in an attempt to improve the dewaterability of the scum. The unit was initially operated for a period of one hour without neutralization to establish base conditions and initial sludge filterability characteristics. During this time, the cake thickness decreased from about 3 mm (1/8") thickness which did discharge, to a very thin 1.5 mm (1/16") thick cake which did not discharge at all. Operating conditions for the system were kept constant at a flowrate of 719 lpm (190 gpm) 53% recycle, a polyelectrolyte dosage of 1.5 mg/l and a 2,000 mg/l calcium chloride dosage. After one hour, concentrated sulfuric acid was then metered into the scum conditioning tank and mixed with the floated scum. The pH of the scum was monitored manually and the acid dosage adjusted to allow a gradual decrease in pH from an untreated scum pH of 11.4 to a low pH of 1.5.

Although the filter cake from the acid conditioned sludge darkened in color, as was observed in laboratory tests, there was no apparent increase in the filterability of the scum. Very little cake discharge could be obtained even with the pH of the sludge adjusted.

Wastewater Equalization

Three wastewater treatment system runs were performed on January 9, 10, and 11, 1973 to evaluate the usage of the 32.2 cu m (8500 gal.) linen storage pit as an equalization tank. During this operation, bench scale flotation, chemical treatment, and leaf tests were performed to determine if the full scale units performed in the same manner as the bench tests. The equalization pit was used for the January 10 and 11 testing, but not January 9. These runs were merely performed to establish if the system could be operated consistently using equalization, and as such, detailed laboratory analyses were not performed on the samples obtained.

The basic operating conditions of the three runs are presented in Table 37. The percentage print wipers reported is the percentage of the total industrial wash poundage for that day that was print wipers. The percentage filter blinded reported is the percentage of time during each day's run that the filter cake failed to discharge from the filter drum. On January 9, the unit was run as it has been in the past to establish a base of comparison.

Total solids, suspended solids, and pH analyses were performed on raw wastewater and effluent composite samples, as well as scum samples. On January 9, seven grab samples were obtained, and each one analyzed individually. The averages of these analyses are presented with the analyses of the other composite samples for the runs in Table 38. In general, it appears from Table 38 that the flotation unit performed about the same each day. The only area where the change from no equalization to the use of equalization clearly had an effect is delineated in Table 39, showing that the changeover to equalization on January 10 had a beneficial effect in that the filter never blinded at all.

During the January 9 run, with no equalization, and only 27% print wipers, the filter blinded for one hour when print wiper sludge came through as a slug, and then recovered. On January 10, when equalizing approximately the same proportion of print wiper wastewater, the filter did not blind at all. On January 11, the filter completely blinded even with equalization when treating wastewater emanating from 40% print wipers. Though the scum was thick enough to filter, 6.75% solids, the cake never discharged. This demonstrated that the treatment unit cannot operate consistently without equalization or when the proportion of printer's towels in the wash load is much above 25%. Above this level, the solids present in the printer's towels dominate the wastewater and cause filter blinding. There is then too much print wiper wastewater present to dampen its adverse filtration effects by equalization.

The cake solids and yield data presented in Table 39 is misleading as the scum suspended solids vary significantly and consequently affect filter performance. The variability of the scum solids makes it difficult to compare vacuum filter results over any length of time. The basic criterion of importance for the vacuum filter is that it produce a relatively dry cake at a rate compatible with the flotation unit. Thus the vacuum filter does best when the wastewater is equalized with the printer's towels at an acceptable proportion of the wash load.

The flotation, chemical treatment, and vacuum filter bench tests performed provided results reasonably similar to the full scale operation. The performance of the treatment system could be simulated by bench scale

TABLE 37

WASTE TREATMENT SYSTEM OPERATING CONDITIONS OF JANUARY 9 to 11, 1973

Parameter	January 9 No Equalization	January 10	January 11
$CaCl_2$ dosage - mg/l	1,690	2,720	2,590
A-23 Dosage - mg/l	1.5	0.5	1.8
Avg. Raw Flow - lpm	473	473	613
Recycle - %	80	80	70
Length of Run - hours	5.62	3.14	2.85
Print Wiper - % of Industrial Washload	27	21.6	39.5
Filtrate Flow - lpm	44	50	--
% of Time Filter Blinded	18	0	100
Sludge Volume - 1/1000 l raw waste	42	20	0
Surface Overflow Rate, lpm/sq m	85	85	106
Equalization Time - hours	1.13	1.13	0.87

TABLE 38

LABORATORY ANALYTICAL RESULTS FOR JANUARY 9 to 11, 1973

Parameter	January 9	January 10	January 11
Scum Total Solids - %	5.33	4.13	7.78
Scum Suspended Solids - %	4.10	2.60	6 75
Raw pH - units	11.05 to 11.75	11.6	--
Effluent pH - units	11.1 to 11.85	11.1	--
Raw Total Solids - mg/l	9,279	5,770	8,564
Effluent Total Solids - mg/l	3,933	3,678	4,817
Raw Suspended Solids - mg/l	2,705	2,285	3,916
Effluent Suspended Solids - mg/l	510	795	516
Vacuum Filtrate pH - units		11.9	
Vacuum Filtrate Total Solids - mg/l		5,340	
Vacuum Filtrate Suspended Solids - mg/l		580	
Effluent Grease - mg/l	384	312	271

TABLE 39

VACUUM FILTER RESULTS FOR VARIOUS RATIOS OF PRINTER'S TOWELS

% Printer's Towels	% of Time Filter Blinded	Cake Solids (% Dry Solids)	Yield (kgs/sq m/hr)
0% - no equalization	0%	48.23	30.5
21.6% - equalization	0%	24.97	19.6
27.0% - no equalization	18%	26.85	29.1
39.5% - equalization	100%	0	0
100% - no equalization	100%	0	0

testing for all unit processes, while performing them side by side with the large system.

At this time, it was discerned that samples of flotation tank effluent developed a considerable amount of afterfloc on standing overnight. Afterfloc is the condition of precipitation or solids crystalization occurring in a water. Thus the mechanism creates suspended material that can be measured as suspended solids. The walls of glass sample containers were observed to often be coated with a hard scale. Tests were conducted in the laboratory to determine whether afterfloc and scale formation might be reduced by increasing the amount of time between the addition of calcium chloride and the polyelectrolyte. The present system operation only allowed 1 to 2 minutes with the calcium chloride being added first, and it was suspected that the polyelectrolyte may have been tying up the calicum chloride floc too quickly, thus not allowing it to complete its chemical reactions.

These tests were performed on the January 9, 1973 wastewater composite, and the results are presented in Table 40.

It was found that increasing the length of time between chemical additions could reduce afterfloc formation. Table 40 shows a definite increase in turbidity and a reduction in silica concentration for the chemically treated wastewater with increased time between chemical additions, thus showing that silica is precipitating while the samples stand. It is known that the calcium chloride precipitates the majority of the silicates present in the wastewater (see Tables 28 and 29). From this testing, it was evident that two minutes did not allow this reaction to go to completion.

This phenomenon influenced all effluent suspended solids analyses up to January 11, 1973 and could probably account for a significant portion of the variability encountered in effluent suspended solids data to this date. The samples often were several days old before analysis due to the distance from the treatment site to the laboratory. Thus, afterfloc could cause effluent suspended solids to appear much higher than they actually were and account for the differences observed between the initial bench tests and field performance.

Based on the operation of the industrial laundry wastewater treatment system, the following changes in the treatment system were implemented:

1. Wastewater equalization of at least 1 hour required for consistent treatment unit operation.

2. Only 25% of the industrial wash load could be printer's towels during any treatment system operating day at any one time during the day.

TABLE 40

EFFECT OF VARYING TIME INTERVAL BETWEEN CALCIUM CHLORIDE ADDITION AND POLYELECTROLYTE ADDITION ON AFTERFLOC FORMATION FOR INDUSTRIAL LAUNDRY WASTEWATER

Time Interval	Turbidity, FTU		Si, mg/l as SiO_2			After Floc Formation
				After 1 Day		
	Initial*	8 hrs Later	Initial	Total	Supernatant	
1/2 minute	33	40	60	45	13	Formed within 5 min.
1 minute	48	48	54	39	13	Formed within 15 min.
2 minutes	23	34	43	24	15	Formed after 1 hour
5 minutes	21	32	47	24	19	Formed within 8 hours
10 minutes	17	20	34	28	28	No after floc
30 minutes	13	14	24	21	19	No after floc

* Measured within 30 minutes of A-23 addition.

Test Procedure: 2000 mg/l $CaCl_2 \cdot 2H_2O$ added to waste, mixed 10 seconds, then allowed to stand 1/2, 1, 2, etc. minutes. 2 mg/l A-23 was then added, the waste mixed 1 minute and the floc allowed to settle. Hanging floc was removed by filtration through 541 paper. The filtrate was then allowed to stand to observe afterfloc formation.

Results:

1. The initial turbidity readings for the 1/2 and 1 minute tests include afterfloc already formed. After 8 hours, the afterfloc was very large and did not indicate a high turbidity value.
2. Scale formed on the sample container walls during one day storage. The total silica value also decreased.
3. After the afterfloc settled, the supernatant contained significantly less silica indicating that the afterfloc may be a calcium silicate material.

3. Calcium chloride added to the equalization pit to provide the necessary detention time between the addition of calcium chloride and polyelectrolyte. The floc was tough enough that long periods of agitation would not harm it.

OPERATING THE INDUSTRIAL LAUNDRY WASTE TREATMENT SYSTEM WITH EQUALIZATION

The treatment system was operated from January 23, 1973 to January 31, 1973 utilizing industrial laundry wastewater generated when the printer's towel wash load was kept below 20% of the total wash load to prevent filter blinding problems. The equalization pit was used for all runs, theoretically providing 53 minutes to 77 minutes equalization over the range of flowrates studied. During this operation, the chemical dosage and flotation tank overflow rate were varied to study the effect of these two parameters. Composite samples of raw wastewater, flotation effluent, vacuum filtrate, and diatomaceous earth effluent were obtained during each run. Complete analyses including heavy metals were performed on all samples. On two days, January 25 and 30, separate sample sets were obtained when the diatomaceous earth filter was brought into the treatment system after two hours of flotation tank operation. There was a set of samples taken during the flotation tank operation and a set of separate samples obtained after the diatomaceous earth filter came on line.

All operating data and wastewater analyses are reported in Tables C-4, C-5, and C-6 of Appendix C for this test work. It will not be recorded again in this section of the report, since this would be redundant. In the data analysis which follows, two previous tests performed without the additional equalization are also included, because they include a complete set of heavy metal analyses. The data presented in the following tables thus includes ten treatment system tests, two of which did not have equalization. Only seven of the tests were performed utilizing the diatomaceous earth filter.

The calcium chloride dosage and surface overflow rate were varied widely during this testing to determine the effects of these parameters on effluent quality. Likewise, information was obtained on sludge production and operating skill required in order to obtain system operating costs.

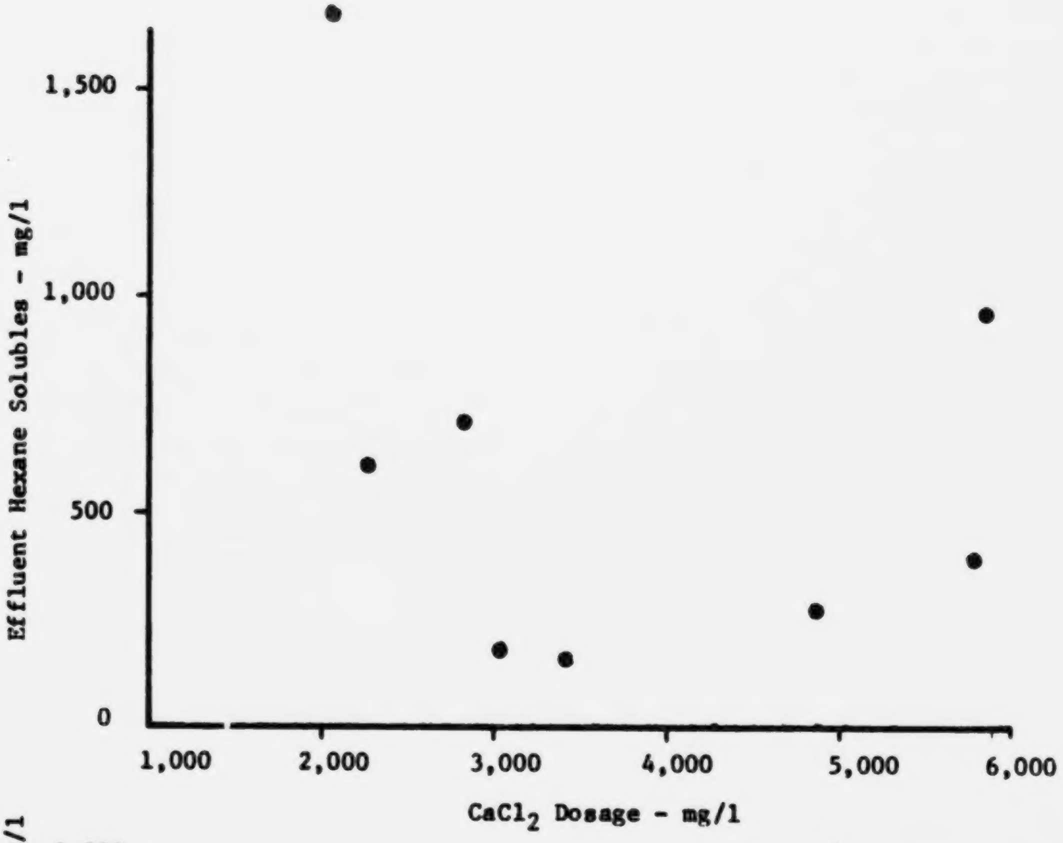
The data obtained from the wastewater treatment system testing was erratic. However, close observation of the results can provide insight into the characteristics of industrial laundry wastewater treatment. Figure 18 demonstrates the variation of flotation effluent grease and suspended solids with calcium chloride dosage and surface overflow rate respectively for the data of Appendix C. The August 9 operation is not included in this graph, because the measurement of the flow rate on this day was open to some question. Likewise, the October 20 suspended solids analysis is open to some question due to afterfloc formation. However, it was evident that for these operating conditions that the effluent suspended solids were much higher than normal. Therefore, this test day is included in the graphs. From Figure 18 it appears that 1000 mg/l calcium chloride is required to break the majority of the hexane soluble emulsion. Much above this level, no additional hexane soluble removal is obtained. Generally, 2,000 mg/l calcium chloride provided a floc of very good appearance, but the additional calcium chloride dosage may be needed to obtain more hexane soluble removal in some cases. Flotation effluent suspended solids were found to be very dependent on surface overflow rate, increasing rapidly at overflow rates greater than 98 lpm/sq.m (2.4 gpm/sq ft). Operating much below 94 lpm/sq m (2.3 gpm/sq ft) did not enhance effluent suspended solids greatly. The optimum overflow rate of the unit was then about 90 lpm/sq m (2.2 gpm/sq ft). It is desirable to keep the flotation effluent suspended solids low to prevent plugging of the DE filter.

That the operation of the flotation system was improved by the system changes is evident in Table 41 which presents some average flotation effluent analyses of October and November, 1973 versus the January 23 to January 31, 1973 flotation effluent analyses. Eight January samples are compared to seven previous runs. The effluent hexane solubles show an improvement of 29% and the effluent suspended solids an improvement of 45%. The change in the chemical addition points and equalization helped improve effluent quality, even though the flotation effluent TOC stayed the same.

A least squares regression analysis on the January TOC and grease data demonstrated a correlation coefficient of 0.86 indicating that the majority of the effluent TOC is related to hexane soluble material not retained in the flotation tank. Any improvement in hexane soluble retention would also considerably lower the organic content of the wastewater. Since DE filtration readily sorbs non-emulsified oils, it is to be expected that the DE filtration step would considerably lower the TOC content of the wastewater. As will be seen, this is what happened.

Other attempts at correlating the mass loading of the flotation unit, overflow rate or calcium chloride dosage with other parameters did not meet with success. This points out that the performance of the unit during this testing was quite erratic, and could not be relied on to do an effective job 100% of the time. This also demonstrates the complexity of the wastewater being dealt with, and the undoubtedly many intricate chemical and physical phenomena associated with this wastewater. Because of this, the performance of the industrial laundry wastewater treatment system will be discussed on only a gross basis.

The erratic performance was also influenced by the equalization basin initially, as a lot of material settled in the basin, and did not show up in the raw wastewater samples obtained going to the pit. Later the same material was resuspended and appeared at the inlet of the flotation tank. Therefore, the raw wastewater sample point varied during the course of the January, 1973 testing to reflect this trend. The first two system runs, January 23 and 24, indicated very low raw grease and suspended solids analyses which led to concern that a lot of material was settling in the equalization pit. Upon using the pit entrance for the raw sample point during the January 25 run, the suspended solids and grease immediately increased. This demonstrated that the contents of the equalization pit



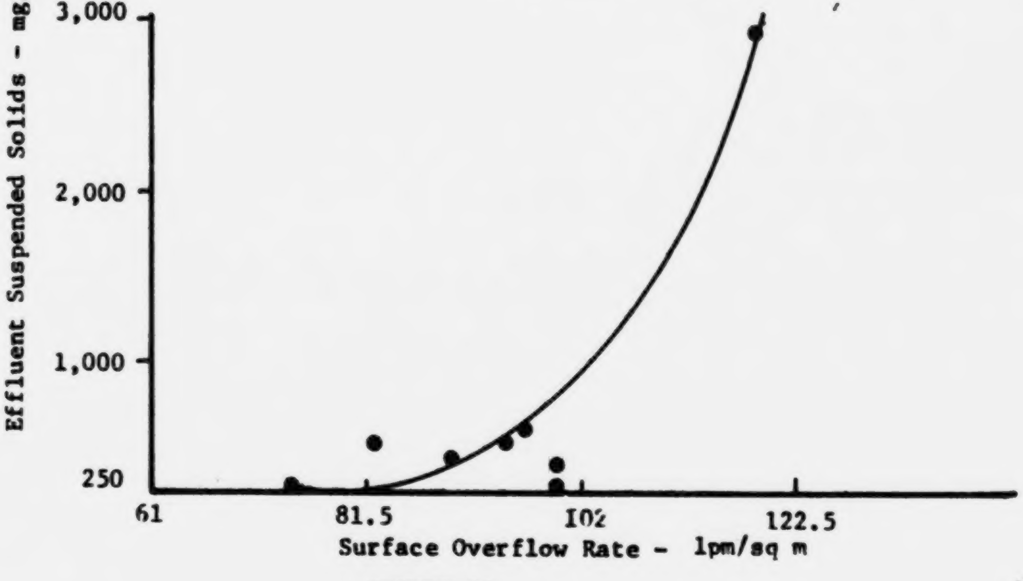


FIGURE 18
EFFECT OF CALCIUM CHLORIDE DOSAGE ON FLOTATION
EFFLUENT GREASE AND SURFACE OVERFLOW RATE ON EFFLUENT SUSPENDED SOLIDS

TABLE 41

CHANGES IN FLOTATION EFFLUENT QUALITY WITH TREATMENT SYSTEM CHANGES

	Oct. - Nov. 1972	January 1973
Effluent Suspended Solids, mg/l	1230	674
Hexane Solubles, mg/l	872	620
TOC, mg/l	1049	1077

were not mixed well enough. However, there was not time available to rectify this problem before completion of the industrial laundry test work.

Table 42 presents the average removal of various industrial laundry wastewater contaminants by the flotation unit and the diatomaceous earth filter. Table 43 presents the average contaminant concentrations for these same runs utilizing all the data presented in Table C-6 of Appendix C. Each specific point on these two tables is the average of all numbers available for that point. The number of observations for each point is in parenthesis beside each observation.

It is apparent when considering these two tables that the system does not readily remove BOD. When comparing the BOD values to the total organic carbon, it is also evident that much of the organic material is not measured as BOD. There is some amount of organic solvents and hydrocarbons present that are probably refractory or non-biodegradable under certain conditions. These materials can come from the printing industry which utilizes various solvents for scrubbing presses or from an oil which is added to the dust mops to provide them with the power to pick up dirt particles. These refractory compounds also have other sources. A large portion of this organic fraction is removed after the wastewater oil emulsion is broken, since the fraction lighter than water will readily separate in the flotation tank. After flotation, the remaining particulate matter and oil is readily separated and absorbed by the diatomaceous earth filter. The remaining TOC is mostly the soluble non-hydrocarbon organic fraction which is probably biodegradable.

It may be noted in Table 43 that there are considerable amounts of heavy metals in the wastewater, most notably zinc, lead, and copper. These metals may affect the BOD analyses at some point during the incubation period. Laboratory studies demonstrated no lag time during the incubation period, but they did demonstrate that almost 100% of the BOD was exerted in 5 days, possibly indicating toxicity at some point before the 5 day period or before the ultimate 20 day BOD is exerted.

From the TOC/BOD ratio of Table 43, it appears that the presence of refractory organics cause a high TOC/BOD ratio (average = 2.5) in the raw wastewater, since theoretically this ratio can be as low as 0.375 for simple organic compounds. Thus much of the TOC is not oxidized by bacteria. The presence of toxic heavy metals would also tend to suppress BOD values by killing bacteria available to oxidize the organic matter. However, the exact effect these metals might have on sample BOD is not readily discernable since a fraction of the metals are present as water insoluble forms and as such would not be toxic during the BOD test. Of course, a certain fraction is always soluble. It may be noted that the TOC/BOD ratio decreases as the wastewater proceeds through the treatment system indicating that the bacteria are more readily able to oxidize the organics present. This phenomenon could be due to reduction of heavy metal toxicity or refractory organic removal in the treatment system. Based on these findings, it is doubtful if BOD is a meaningful parameter for this type of wastewater.

TABLE 42

WASTE TREATMENT EFFICIENCIES FOR VARIOUS PARAMETERS IN INDUSTRIAL LAUNDRY WASTE TREATMENT

Parameter	Average % Removed by Flotation	Average % Removed by System
BOD	24.4 (6)	57.1 (3)
TOC	50.1 (10)	74.0 (6)
Suspended Solids	70.0 (9)	88.7 (9)
Total Solids	25.2 (10)	33.7 (7)
Hexane Solubles	48.2 (9)	83.4 (7)
Copper	64.8 (8)	68.2 (6)
Lead	59.5 (8)	69.5 (6)
Mercury	56.5 (5)	70.8 (5)
Cadmium	26.7 (8)	35.4 (6)
Zinc	83.3 (8)	96.5 (6)
Chromium	21.1 (8)	20.6 (8)
Iron	83.3 (8)	92.8 (6)
Nickel	29.4 (8)	29.3 (6)

TABLE 43

AVERAGE CONTAMINANT CONCENTRATION ACHIEVED IN THE INDUSTRIAL LAUNDRY TREATMENT SYSTEM

Parameter	Raw Waste	Flotation Effluent	Diatomaceous Earth Effluent
BOD, mg/l	830 (6)	611 (6)	335 (3)
Suspended Solids, mg/l	2809 (9)	674 (9)	87 (6)
VSS, % of Sus. Solids	62.7 (7)	82.2 (7)	75.8 (4)
TOC, mg/l	2482 (10)	1067 (10)	362 (6)
Total Solids, mg/l	6748 (5)	4693 (10)	4073 (7)
VTS, % of Total Solids	31.5* (3)	25.7 (6)	16.6 (4)
Hexane Solubles, mg/l	1538 (10)	568 (9)	95 (7)
Chromium, mg/l	2.3 (9)	1.8 (8)	2.0 (6)
Copper, mg/l	4.0 (8)	0.7 (8)	0.5 (6)
Lead, mg/l	12.7 (9)	2.3 (8)	1.4 (6)
Zinc, mg/l	3.9 (9)	0.4 (8)	0.1 (6)
Cadmium, mg/l	0.24 (9)	0.23 (8)	0.19 (6)
Iron, mg/l	39.5 (9)	1.4 (8)	0.4 (6)
Nickel, mg/l	1.6 (9)	1.2 (8)	1.2 (6)
Mercury, μg/l	3.3 (5)	1.0 (6)	0.7 (6)
TOC/BOD	2.5 (6)	1.5 (7)	1.25 (4)
Alkalinity to pH 8.3 mg/l as $CaCO_3$,	326* (4)	152 (5)+	142 (3)+
Alkalinity to pH 4.5 mg/l as $CaCO_3$,	1725* (4)	295 (5)+	249 (3)+

* To pit without CaCl2 addition
+ without H_2SO_4 neutralization

Table 42 and 43 demonstrate that suspended solids and grease are readily removed by the treatment system. Approximately 80% of the hexane solubles and 90% of the suspended matter are removed by the two process elements. It is also evident from Table 43 that the flotation effluent needs further treatment to reduce hexane solubles, BOD, suspended solids, and certain heavy metals to more acceptable levels. Even the diatomaceous earth filter effluent does not provide the degree of treatment required for all the parameters as specified in the Chicago ordinance of Table 4. The average lead and mercury are slightly above the allowable limits. Dependent upon the wastewater treatment objectives, some form of post treatment after diatomaceous earth filtration may be required to meet specified levels of certain contaminants.

A great deal of treatment system variability in performance was noted, as demonstrated in Tables 44 and 45. The large range of removal percentages is significant, and is influenced somewhat by the wide range of raw wastewater contaminant concentrations. When the influent heavy metal concentration is low or near its limit of solubility, then the percentage removal of this element approaches zero. This causes the performance of the wastewater treatment system to appear much more erratic than it actually is for these elements. It may be noted from Table 42 that the average removal percentages for these elements other than nickel, chromium, and cadmium are all near 70%; thus indicating that the removal percentages of the heavy metals are generally toward the high side of the ranges shown in Table 44.

Because the pH of the wastewater is commonly greater than 10 after the calcium chloride addition, it is evident that most of the metallic compounds are present as hydroxide precipitates of some form. Consequently, a liquid solids separation device is capable of removing heavy metals. It may be noted that if more conventional coagulants such as alum or ferric chloride were utilized, the pH required for chemical treatment would probably have to be between 4 and 6.5. Such being the case, many of the metals removed at an elevated pH would not be soluble and remain in the wastewater. Calcium chloride chemical treatment will only work at an elevated pH, consequently heavy metal removal is a beneficial side effect.

The treatment system has its greatest difficulty in removing nickel, chromium, and cadmium. The chemical and physical pehnomena that may be causing this are not well defined, because of the complex chemical nature of the wastewater and the chemical treatment characteristics.

It can be observed that copper, lead, iron and zinc are consistently removed in the treatment system. The removal of certain heavy metals and what fraction of heavy metals are removed is undoubtedly affected by wastewater pH, organic and inorganic metallic complexing, calcium chloride dosage, the chemical structure of the metallic compounds, wastewater temperatures, solution ionic strength, compound solubilities, and various other items that affect reaction kinetics and chemical equilibria. It is difficult at best to identify the exact removal mechanism for a specific heavy metal. However, it may be noted that, even though the cadmium, nickel, and chromium were not removed to any great or consistent

TABLE 44

RANGES OF WASTE TREATMENT EFFICIENCIES FOR THE INDUSTRIAL LAUNDRY WASTE TREATMENT SYSTEM

Parameter	Range of % Removals by Flotation	Range of % Removal by System
BOD	0 - 67	48 - 73
TOC	0 - 93	54 - 95
Suspended Solids	38 - 98	79 - 99
Total Solids	0 - 54	5 - 57
Hexane Solubles	0 - 95	34 - 99
Copper	0 - 93	0 - 73
Lead	17 - 99	40 - 99
Mercury	0 - 91	33 - 91
Cadmium	0 - 95	0 - 95
Zinc	36 - 99	89 - 99
Chromium	0 - 73	0 - 88
Iron	62 - 99	85 - 99
Nickel	0 - 70	0 - 80

TABLE 45

RANGES OF WASTEWATER QUALITY FOR THE INDUSTRIAL LAUNDRY WASTEWATER TREATMENT SYSTEM

Parameter	Raw Waste	Flotation Effluent	Diatomaceous Earth Effluent
BOD, mg/l	647 - 1314	313 - 1167	319 - 353
Suspended Solids, mg/l	649 - 4950	108 - 2914	9 - 174
VSS, % Suspended Solids	54.5 - 64	68.2 - 95.1	60.6 - 89.9
TOC, mg/l	950 - 6300	370 - 2080	123 - 470
Total Solids, mg/l	4856 - 8649	3452 - 6670	2876 - 5609
VTS, % Total Solids	21.3 - 43.9	14.7 - 47.6	12.5 - 20.0
Hexane Solubles, mg/l	403 - 3756	146 - 1663	16 - 266
Chromium, mg/l	1.0 - 3.6	0.9 - 3.2	0.3 - 3.9
Copper, mg/l	0.2 - 9.3	0.3 - 1.5	0.2 - 0.7
Lead, mg/l	3.0 - 35.8	0.35 - 3.3	0.1 - 2.2
Zinc, mg/l	0.55 - 8.9	0.02 - 0.6	0.02 - 0.18
Cadmium, mg/l	0 - 0.6	0.02 - 0.40	0.01 - 0.35
Iron, mg/l	3.5 - 126	0.8 - 2.5	0.2 - 2.4
Nickel, mg/l	1.0 - 2.5	0.3 - 2.0	0.2 - 1.8
Mercury, µg/l	1.2 - 7.0	0.5 - 1.2	0.5 - 1.2
pH, units	10.2 - 11.9	10.1 - 11.5	9.8 - 11.45

extent, the effluent concentrations of these materials still meet the majority of municipal sewer ordinances. It can be concluded that this treatment technique will remove a significant amount of heavy metals from industrial laundry wastewater.

System effluent quality data in Table 45 demonstrate that very high quality water can be produced by the waste treatment system at times. Effluent suspended solids of 9 mg/l and hexane solubles of 16 mg/l are exceedingly low. Likewise, almost all the heavy metals were removed to levels less than 0.3 mg/l at one time or another. From Table 43, the average wastewater DE effluent quality obtained was quite good, and suitable for discharge to almost all sewers. A large amount of the organic matter remaining (TOC) was associated with the dye used at the laundry, as the effluent was always a pale orange.

Two of the tests performed exhibited no reduction for TOC and grease in the flotation process, but the diatomaceous earth filter demonstrated 60% to 80% removals for these contaminants during the same runs. Thus, there were time periods when the flotation tank was not functioning as desired, and the diatomaceous earth filter acted as the primary solids separator. Thus the DE filter provides a good backup to the flotation tank, if it is upset for short time periods.

Because of the erratic performance of the treatment system, it may be desirable to have a form of post treatment after the DE filter. This could be a variety of treatment modules - mixed media filters, activated carbon, demineralizers of various types, chemical oxidation, etc. - dependent on the contaminant under consideration. For heavy metals, the post treatment would have to be somewhat more sophisticated, especially if the remaining metals are dissolved. Here, ion exchange or reverse osmosis might be in order. Research would be required in this area to establish what would work and determine what operational problems might be encountered. For high hexane soluble or organic contents, extra DE filter capacity or activated carbon columns would provide the desired effluent quality. In some instances, no additional treatment will be required, especially for lower strength wastewaters. It is felt that the present treatment technique could provide more consistent results if more equalization time, and better equalization mixing were available, as well as more detention time in the flotation unit to allow this unit to better handle short surges of high strength wastewater and provide better solids separation. Twenty minutes effective detention time would be more desirable than the ten minutes presently available at an overflow rate of 90 lpm/sq m (2.2 gpm/sq ft).

During the industrial laundry operation, it was discovered that the diatomaceous earth filter was not being properly backwashed, because of a lack of sufficient backwash water. Backwashing the filter at a low flow rate causes only part of the filter cake to discharge leaving much of the dirty cake on the filter septums. This soon leads to areas of the filtration surface becoming completely blinded and bridging of the filter septums occurs. Consequently, the head loss of the filter builds up more quickly than it otherwise would, and the effective filtration area is decreased.

This leads to a higher hydraulic loading and a deterioration in effluent quality. It may be noted that the earlier runs of the DE filter, August 9, 1972 and October 20, 1972, produced effluent much superior to the January effluents. Likewise, so did the January 30, 1973 run when the problem was recognized, and the filter cleaned by hand. It is strongly felt that the need for post treatment is considerably reduced with this problem rectified, and the DE filtration process properly operated.

The DE backwash during this testing was directed to the heat exchanger pit. In normal practice, it would be beneficial to direct this flow to another tank of about 4,000 liters (1000 gal.) capacity to collect the backwash. This could then be fed to the vacuum filter at a controlled rate for dewatering with the laundry scum. In summary, it is evident that calcium chloride chemical treatment at a high pH followed by solids separation is an effective grease and heavy metal separating technique.

From Table C-4 of Appendix C, it is apparent that even after the printer's towel wash load was controlled and equalization provided, filter blinding still manifested itself at times, especially when the printer's towels were near 20% of the wash load. During the January 26, 1973 operation, the filter blinded completely due to short circuiting in the equalization basin. No detention time could be maintained in the equalization basin, due to the low flow rate coming to it. Consequently, the wastewater that flowed in was almost immediately pumped out. If this day is ignored, it is evident that when the printer's towels are kept at 15% of the industrial wash load at any one time, and with approximately one hour equalization, vacuum filter cloth blinding is not a problem.

The amount of sludge generated was significant, and the volume produced varies directly with the moisture content of the sludge. Generally, the cake solids obtained were between 25% and 30%. No attempts were made to optimize the vacuum filter performance, as it nicely kept up with the scum generated at its lowest cycle time, 5.5 minutes. The submergence varied with the on-off cycling of the skimmer, but this was not a problem, as a cake thick enough to discharge was produced. Generally, the vacuum filter produced 20 to 40 liters of sludge/1000 liters of raw wastewater treated. The final waste to be disposed of is then about 3% of the design flow rate.

During the operation of the system, a check valve on the acid neutralization system failed such that only limited neutralization data could be obtained. This part could not be replaced prior to the completion of the project. The information obtained indicated that 200 to 400 mg H_2SO_4/l of wastewater would keep the effluent pH below 10.0. The alkalinity data obtained from those samples without acid neutralization indicated that 100 to 250 mg H_2SO_4/l would be sufficient to neutralize the flotation effluent pH to 8.3. Thus, it appears that 200 mg/l H_2SO_4 is generally sufficient to neutralize this wastewater to a level suitable for sewer discharge.

During this test work, body feeding the DE filter did not seem to provide a great increase in the length of filtration runs. Because the solids are flocculant, they are of a blinding character such that when they are filtered by the DE, they plug that portion of the filtration surface. Consequently, DE body feed should be beneficial in that this provides a new relatively clean, filtering surface. However, the variation in suspended solids from the flotation unit masked any effect the body feed rate may have had. When the flotation unit was upset, the pressure differential built up quickly, and body feed would not have significantly altered this rate, e.g. October 20, 1972. The character of the other runs are masked by the problems discussed previously. When the flotation unit worked well, little pressure buildup was measured indicating that if the flotation unit performs consistently, a full shift run may be obtained at hydraulic loadings of 12 to 20 lpm/sq m (0.3 to 0.5 gpm/sq ft) and a flotation effluent containing 100 mg/l to 250 mg/l suspended solids. Thus DE filtration can be an attractive process for industrial laundry wastewater treatment in that it is highly efficient at separating solids, utilizes little floor area, and absorbs oils and greases.

Optimum Treatment System Operating Conditions

Based on the above data and many months experience with the treatment system, the optimum operating conditions of the wastewater treatment system were defined and are presented in Table 46. Originally the system was designed for an overflow rate of 114 lpm/sq m, (2.8 gpm/sq ft) a design flow of 757 lpm,(200 gpm) and 378 lpm (100 gpm) pressurized flow or 50% recycle, where percent recycle is defined as pressurized flow over raw flow. However, system operation demonstrated that the optimum overflow rate of the system is 90 lpm/sq m (2.2 gpm/sq ft) and that 100% recycle rather than 50% is desirable due to the large concentration of flocculated solids present. This means the flotation tank has an optimum flowrate of 446 lpm (118 gpm). The optimum detention time associated with this flow should be at least 15 minutes. Table 46 reports only 10 minutes for this system due to the limited size of the flotation unit.

A calcium chloride dosage of at least 2,000 mg/l as determined by field observation is required to insure adequate chemical treatment at all times. The polyelectrolyte is required to strengthen the floc though its dosage is not critical provided it is above 1.0 mg/l. Likewise, the time between chemical additions is not critical provided it is greater than about 30 minutes. Generally the vacuum filter can be operated at a cycle time of 5 minutes and filter all the sludge generated. Pickup time and vacuum level are not critical. The diatomaceous earth filter operated satisfactorily when the flotation unit operates well. A flotation unit operated at the above conditions would provide the consistency required for the DE filter. Therefore, a body feed ratio of 1 to 2 parts DE per part of suspended material should prove adequate to achieve an 8 hour DE filter run, if a 5.3 kg/sq cm (75 psi) differential pressure buildup is allowed at low hydraulic loadings. This may not always be the case if a flotation upset occurs. Another problem is significant variation in flow may cause

TABLE 46

GENERAL OPTIMUM OPERATING CONDITIONS FOR THE INDUSTRIAL LAUNDRY WASTE TREATMENT SYSTEM

Flotation Overflow Rate Based on Raw Flow	446 lpm/sq ft
Flotation Recycle	100%
Flotation Detention Time	10 minutes
% Print Towels in Washload	<15
Equalization Time	1 hour
$CaCl_2$ Dosage	2,000 mg/l
Polyelectrolyte Dosage	2 mg/l
Detention Time Between Two Chemical Additions	1 hour
Vacuum Filter Cycle Time	5 - 5.5 minutes
Vacuum Filter Pickup Time	1.0-1.5 minutes
Vacuum Filter Vacuum Level	>25 cm Hg.
DE Filter Hydraulic Loading	163 lpm/sq m
DE Precoat	0.74 kg/sq m
DE Body Feed	1-2 parts DE to 1 part suspended solids

a loss of filter cake yielding poor effluent quality. Based on the operation of the treatment system, it is also desirable to keep printer's towels at less than 15% of the industrial wash load to prevent all vacuum filter blinding. Table 46 summarizes all of these observations.

Table 47 presents the general operating results of the treatment system exclusive of effluent quality. The solids rise rates were determined from bench flotation tests in the field performed side by side with the large flotation tank. Approximately 80 to 120 liters of scum are generated in the flotation unit for each 1,000 liters of chemically treated wastewater. Thus scum volume is reduced threefold to fourfold in volume by the vacuum filter, based on an assumed sludge density of 1.13 gm/cc (9.5 lbs/gal.). All sludge volumes were calculated using 1.13 gm/cc (9.5 lbs/gal.) as the density. The final sludge contains 20% to 30% dry solids and a large amount of grease and oil. After the sludge is pumped to a storage bin, it has been liquified to the point where it must be hauled away as a liquid rather than a solid. The sludge production and handling system performed as determined in the preliminary laboratory bench tests after resolving the blinding problem.

The operating costs for the system, as obtained from the field installation are presented in Table 48. The coagulation chemical cost is based upon the addition of 2,000 mg/l calcium chloride and 2 mg/l anionic polyelectrolyte. Neutralization costs are based on neutralizing 200 mg/l excess alkalinity as calcium carbonate with sulfuric acid. Power costs are calculated from 63 total system horsepower and a unit power cost of 2¢/kw hr. Material and maintenance costs are calculated on the basis of one man being needed half time to operate the unit at a labor rate of $5.00 per hour. Diatomaceous earth costs are based on utilizing 200 mg/l (1.6 lbs/1000 gal.) of diatomaceous earth as body feed. Sludge disposal costs are $0.012 per liter ($0.045 per gallon) of sludge.

Capital costs are based on a 20 year life for the system recovered at a 6% interest rate, with an initial investment of $74,298 installed, in 1971 dollars. The unit amortization operating cost is of course influenced by the number of shifts the laundry operates; the more shifts the laundry operates, the lower the unit cost. It has been assumed that this treatment unit operates for 8 hours at 446 lpm (118 gpm). If the unit is operated beyond the 8 hour period at a one shift laundry, extra operating labor cost will be required. This tends to offset any gain in treating more water (stored in the equalization tank) to bring the amortized operating cost down. The fixed amortized cost is $24.39/day. For a one shift operation, the amortization cost is 11.6¢/cu m (44¢/1000 gal.); for a two shift operation, the amortized cost is 5.8¢ cu m (22¢/1000 gal.); and for three shifts, 4¢/cu m (15¢/1000 gal.). It is evident that amortized capital costs will vary from laundry to laundry dependent on interest rates, operating labor rates, hours worked, length of time desired to recover investment, initial investment, size of equipment, etc. As an example, a 12 year life at 6% would provide amortized costs of 16.6¢/cu m (63¢/1000 gallons) for a one shift operation, 8.4¢/cu m (31¢/1000 gal.) for two shifts, and 5.5¢/cu m (21¢/1000 gal.) for

TABLE 47

INDUSTRIAL LAUNDRY WASTEWATER TREATMENT SYSTEM

OPERATING RESULTS

Flotation Scum Volume	80-120 1/1000 1 raw flow
Sludge Volume	20-40 1/1000 1 raw flow
Sludge Moisture	70 to 80%
Filter Yield	19.6 to 39.4 kg dry solids/sq m/hr
Filter Blinding	0 to 10%
Solids Rise Rate	0.12 - 0.3 mpm

TABLE 48

INDUSTRIAL LAUNDRY WASTE TREATMENT COSTS IN ¢/CUBIC METER

Item	Cost
Coagulation Chemicals	22.5 (16.2)[b]
Neutralization	1.8
Sludge Disposal	27.2
Power	2.6
Material & Maintenance	6.6
Amortization - 20 years @ 6%	11.6
Diatomaceous Earth	4.2
TOTAL Cost for Sewer Disposal	76.5 (70.2)[b]
Present Washroom Costs[a]	7.9 - 18.5

[a] From laundry wastewater survey

[b] If chemicals bought in bulk

three shifts. The reader may calculate his amortized rate using any table of capital recovery factors for any design life or interest rate desirable. Ten percent may be added to the capital cost of the unit to cover wastewater system engineering. A detailed breakdown of the demonstration system capital costs is given in Appendix E.

The sludge volume was assumed to be 23 1/1000 1 (23 gal./1000 gal.) of wastewater, the average of all runs in Table C-4 except for October 20, 1973, which had abnormally high cake solids. The total operating cost is almost $0.80/ cu m ($3.00/1000 gal.) of wastewater. This can be reduced by $0.063/cu m ($0.24/1000 gal.) if the calcium chloride is handled in bulk as a liquid rather than as individual bags of pellets as was done during this project. The costs presented can be expected to vary from day to day due to different wash loads and different wastewater alkalinities.

The wastewater treatment system operating cost is considerably greater than present average laundry washroom costs of $0.079 to $0.185/cu m, 1971 dollars, (0.30-$0.70/1000 gal.) of raw water. This cost range includes sewer taxes, raw water cost, and sewer surcharges for approximately 70% of a group of laundries surveyed for water consumption and cost information (See Appendix A). Figure 19 is a frequency distribution for the water costs of those laundries surveyed. It is evident from this figure and the treatment system operating cost that water pollution control is not a money making proposition for laundries in general. Because of the wastewater characteristics, three to six times more has to be spent on wastewater treatment than is presently spent on all water related costs.

The operating cost figure given here should not be taken as absolute, however, as this is the cost only for the Roscoe Laundry in Chicago, and applies to industrial (shop towel, printer's towels, and dust mops) laundry wastewater. The treatment costs presented would be expected to decrease for weaker laundry wastewater, since not as much sludge would be generated, and smaller dosages of treatment chemicals possibly could be utilized. This would lower costs significantly as the coagulation chemicals and sludge disposal costs amount to two-thirds of the total treatment cost. Likewise, sludge disposal costs vary from place to place dependent on how the sludge is handled and on sludge moisture content.

INDUSTRIAL LAUNDRY WASTEWATER REUSE TESTING

On January 30, a water reuse test was performed using diatomaceous earth effluent to wash shop towels. This was accomplished by filling one 364 kg (800 lbs) washing machine with effluent to the desired level on a batch basis for each washing operation. The water was then heated to the desired temperature with steam prior to commencing the tumbling action for each wash operation. Samples of each washing machine dump were then taken to be compared to samples taken from each machine dump of a

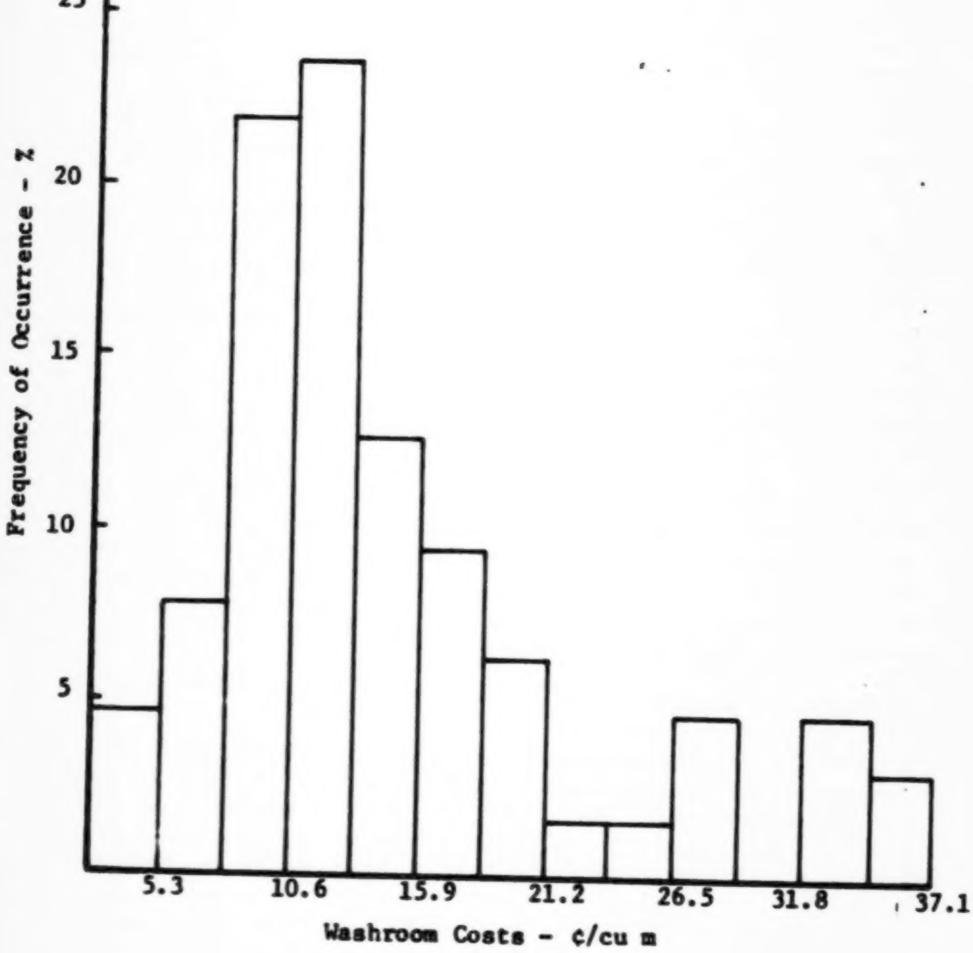


FIGURE 19
LAUNDRY WASHROOM WATER COSTS INCLUDING FRESH WATER
SEWER SURCHARGES AND SEWER USE CHARGES FOR 100 LAUNDRIES

control load of shop towels washed the usual way with softened city water. The same amount of supplies were added to each load. A water absorption test was then performed on each set of cleaned shop towels to compare the degree of cleanliness of both loads of shop towels.

Analyses for grease and TOC were performed on samples obtained from the carryover and ninth rinse cycles of each load. Table 49 presents these results. It may be noted that all analyses in Table 49 indicate higher grease and TOC concentrations for the load of shop towels washed with treated effluent. This could be a result of one load of wipers being dirtier than the other load or to the use of effluent for washing. The water used for washing had a grease content of 82 mg/l. No TOC analyses was available for this water, but it probably measured several hundred ppm.

A test was performed on cleaned wipers from each load washed, whereby the time for several wipers to sink to the bottom of a pail is measured. This is a measure of the water absorptive powers of the wipers. The wipers washed with treatment system effluent took a much longer time to sink than those washed with city water, indicating that the wipers washed with effluent were contaminated with water repelling grease. It was felt by some observers of this test that the reason for this was the heating system utilized for the reused water. In the standard way of washing wipers, the water used to clean them is hot before it enters the machine, whereas the treatment system effluent was placed in the washer cold and heated with steam. Putting cold water into the washing machine after the grease has been emulsified by the supplies and hot water can cause the grease to congeal and reset itself in the wipers. It is therefore not known if the difference in the washed products was due to the water used or the method of heating the water. The results are inconclusive. It may be emphasized here that the wastewater treatment system effluent contains red dye, and as such could not be used to launder anything of a light color.

INDUSTRIAL LAUNDRY WASTEWATER TREATMENT SYSTEM APPLICABILITY

From the foregoing discussion of the wastewater treatment system operation, it is evident that for industrial laundry wastewater of the strength encountered here, the system modifications previously discussed are needed to upgrade the consistency of the treatment process. A larger more completely mixed equalization basin would be desirable in this respect. This would provide more dilution for strong wastes and would provide a surge tank for periods of high flow (many washing machines dumping within a short time interval). This, coupled with consistent backwashing of the DE filter, assists in upgrading the effluent quality to the required standards.

However, the treatment method employed obviously is a good step toward handling metallic and greasy wastewaters emanating from industrial laundries. It may be noted that other laundries using radically

TABLE 49

REUSE WASTEWATER ANALYSES

FOR TWO LOADS OF SHOP TOWELS ON JANUARY 30, 1973

Sample	Wash Operation	Grease mg/l	TOC mg/l
Reused Water	carryover	58,712	62,700
City Water	carryover	49,018	59,300
Reused Water	ninth rinse	604	810
City Water	ninth rinse	383	430

different laundry supplies, e.g. synthetic detergents, may not find this system exactly suitable for their needs. Previously developed laundry treatment processes have extensively utilized alum chemical treatment in combination with various other chemicals (1)(12). Consequently, those laundries utilizing wash formulas other than the caustic, silicate, base oil formula used by Roscoe Co., may find that calcium chloride treatment of their wastewater is ineffective. If alum chemical treatment were utilized at an industrial laundry, it is certain that the scum generated by the flotation process could not be dewatered by conventional vacuum filtration, due to its blinding qualities. It is similar in nature to the print wiper scum. The alternatives would be to haul the scum or dewater it on a DE precoat vacuum filter, both of which would greatly increase already exceedingly high operating costs. Consequently, it is advantageous to stay with calcium chloride chemical treatment if at all possible so that a dewaterable sludge can be obtained (15)(16).

It is certain that preliminary laboratory testing will have to be performed for all industrial laundries contemplating wastewater treatment to identify those chemicals that will effectively treat the wastewater. The samples obtained should be 1 to 2 hour composites to represent the effluent from a moderately sized equalization tank. Likewise, wastewater analyses are required to identify the problem constituents. For industrial laundries, alkalinity and hexane solubles will always be a problem. Therefore, any treatment system installed must effectively deal with these two parameters.

From the data presented, it is obvious that no biological systems will be able to treat industrial laundry wastewater. The toxicity of organic solvents, high temperatures, high pH, and heavy metals is well documented in the literature (13). A chemcial coagulation, solids separation system such as the one demonstrated at the Roscoe laundry is required.

At the present time, the treatment concept outlined here is applicable to those industrial laundries utilizing a wash formula similar to the one herein described. Other wash formulas would require further laboratory work to identify the effect of these different supplies on wastewater treatment. The effect of different types of clientele on wastewater treatment should also be investigated. The customers of the laundry will of course have a marked effect on the character of the wastewater. It is doubtful considering these points and the wastewater variability encountered, space requirements, variation in flow rates, and the particular problems under consideration for each laundry if this system will ever be a standard item. Each one will have to be custom designed to fit that particular laundry's needs, especially in view of the complexity of the wastewater itself. Based on these considerations and the results of initial laboratory testing, it will be desirable in some cases to perform pilot plant studies to further prove the merit of the treatment concept chosen. Erratic laboratory results would indicate the need for pilot plant (40 lpm - 10 gpm) work.

The final factor determining the treatment system concept a laundry owner might employ is of course the cost of the treatment. For industrial laundries, located in areas with presently existing sewer codes regulating discharges, the decision on wastewater treatment will relate to the cost of treatment versus predicted profits. In almost all instances, dependent upon municipal enforcement attitudes, treatment will be required. The costs previously presented cannot of course be taken as absolute due to widely varying circumstances. However, a laundry owner of a medium size - 36,000 to 46,000 kgs (80-100,000 lbs) laundered per week - industrial cleaning company should be prepared to invest at least $40,000 initially and carry a $100 per shift operating cost at the minimum. The Roscoe plant represents a $75,000 investment (1971) dollars) and $250 per day operating costs excluding amortization, due to its exceedingly strong wastewater. The treatment cost at Roscoe is about 2.2 cents per kilogram (1¢/lb) of wipers laundered.

It may be said with impunity that industrial laundries washing shop towels and printer's towels face a significant problem in wastewater treatment. However, this can be resolved through an expensive capital outlay. For those laundries whose wastewater is not as strong as the subject plant, either because of the type of customer or the washing of a significant amount of other items, the alternatives are not as drastic.

In order to more universally apply the data obtained to other laundries, more information is needed on the variability of laundry wastewater characteristics from plant to plant wherein the same items are laundered. Likewise, information on the effect of different laundry supplies on the applicability of the treatment system is required. Information on laundry profit margins would provide a valuable tool for wastewater treatment break even analyses for given laundry mixes and sizes, especially if the variation in wastewater quality from plant to plant were defined from a much more extensive survey than was conducted for this project. This would provide valuable information on the exact magnitude of the laundry wastewater treatment problem, both from a treatability standpoint and governmental attitudes.

SECTION VI

UNIFORM LAUNDRY WASTEWATER TREATMENT

UNIFORM LAUNDRY WASTEWATER QUALITY

The uniform laundry survey was performed at another Roscoe Co. plant also located in Chicago. This laundry was visited on March 23 and 24, 1972, and composite and grab samples of wastewater going to the sewer, and grab samples of individual washing machine dumps obtained. The sampling program was designed to characterize the wastewater discharge from this type of laundry and to provide samples for bench scale testing to determine if the wastewater treatment techniques recommended for the shop and printer's towels would also apply to this wastewater.

This laundry has a wastewater flow of about 284 cu m per day (75,000 gpd) with a weekly wash load of 36,000 to 41,000 kgs (80-90,000 lbs). The plant washes synthetic shirts and pants of various colors, entrance mats, cottons, uniforms, and some print wipers. The basic supplies include caustic, sodium metasilicate, and a nonionic detergent (base oil). Trichloroisocyanuric acid is used as a bleach, sodium silicofluoride as a sour, and a quaternary ammonium compound as a mildicide. Starch is also utilized. All samples from the washing machine dumps were analyzed for total solids, total organic carbon, and pH; with selected samples analyzed for grease and suspended solids. The effluent composites were analyzed for these and other compounds and subjected to bench scale flotation tests.

The results of a series of analyses for loads of synthetic pants, synthetic shirts and uniforms, (coveralls and pants) are presented in Tables 50, 51 and 52, respectively. From these tables, it can be noted that TOC, total solids and pH decrease with each succeeding rinse and total solids and TOC increase with an addition in supplies, notably the break and starch operations. By comparing these tables with Tables 7, 8 and 9 which present similar data for wipers and dust mops, it is evident that uniform laundry wastewater is not as potent as that emanating from wipers and dust mops. In fact, the TOC and total solids appear to be 5 to 10 times less for uniforms. It may be noted that the suspended solids and grease contents of the suds operations for uniforms were of the same level as the composite sewer effluent samples obtained from the industrial laundry, indicating that the average industrial laundry wastewater pollutional load is equivalent to the worst pollutional load generated by uniforms. Considering the nature of each article's use, it is evident that

TABLE 50

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION FOR SYNTHETIC PANTS

Operation	Grease mg/l	Suspended Solids-mg/l	TOC mg/l	Total Solids mg/l	pH Units
Break	2,570	2,780	6,396	21,783	12.8
Carry Over			3,520	13,429	12.7
Break			1,604	7,220	12.55
Rinse 1			958	3,392	12.3
Rinse 2			649	1,781	12.05
Rinse 3			379	1,763	11.75
Rinse 4			264	1,342	11.5
Rinse 5			214	1,145	11.25
Rinse 6			79	534	10.2
Sour	321	110	78	1,011	5.15
Starch			575	1,833	6.7

TABLE 51

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION FOR SYNTHETIC SHIRTS

Operation	Suspended Solids-mg/l	TOC mg/l	Total Solids mg/l	pH Units
Suds	3,120	4,090	21,916	12.35
Flush		1,706	6,990	11.95
Suds		1,822	12,755	12.75
Rinse 1		804	5,016	12.4
Rinse 2		350	2,423	12.1
Rinse 3		200	1,212	11.75
Rinse 4		130	794	11.25
Rinse 5		96	570	10.4
Rinse 6	86	66	460	10.1
Sour		90	612	8.1
Starch		3,109	7,515	7.55

TABLE 52

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION FOR UNIFORMS

Operation	Grease mg/1	Suspended Solids-mg/1	TOC mg/1	Total Solids mg/1	pH Units
Suds	1,700	860	5,034	15,931	12.5
Carryover			5,544	12,448	12.45
Rinse 1			1,856	4,383	12.1
Rinse 2			586	1,888	11.6
Rinse 3			259	765	10.85
Rinse 4			117	420	10.15
Rinse 5			83	498	9.7
Rinse 6			57	360	9.5
Sour	36	176	50	1,684	4.7
Starch			1,938	4,331	4.85

the uniforms do not undergo the severe treatment that shop towels do, even if both are used in the same industry. The shop towels are used specifically for wiping things up, while the uniforms are used only for protecting the workers, and generally are not used for direct cleaning up.

The variation in wastewater quality between wash operations is very large, and again demonstrates the tremendous potential for variation in laundry wastewater quality. Table C-2 of Appendix C presents the results of analyses performed in this same survey.

Table 53 presents the water quality of final rinses of various washed items. A fairly consistent quality is indicated for the uniform items in that total solids fall between 360-534 mg/l, the pH between 9.5-10.2, and the TOC between 57-79 mg/l. By comparison, stronger final rinses can be noted for entrance mats and print wipers. In fact, the final rinse quality is similar to that obtained for linens, although the breaks contain a larger amount of contamination than the linens. (See Section VII of this report.) Comparison of Table 53 with Table 10 also aptly demonstrates the weakness of uniform wastewater compared to that of industrial items. Final rinse TOC, suspended solids, and total solids are all several times lower for uniforms, even when comparing the sixth or seventh rinse of uniforms to the tenth or eleventh rinse of wipers.

Table 54 summarizes the analyses performed for the various articles sampled in terms of kilograms of TOC and total solids per 100 kgs of articles laundered. The uniform plant wastes generated about 2.3-2.5 kgs TOC/100 kgs laundered and 7-9 kgs total solids/100 kgs laundered. Comparing this table to Table 11 demonstrates that uniforms produce only 5% to 10% of the wastewater TOC generated by wipers and 20% of the TOC generated by dust mops. The uniforms produced only 10% to 20% of the total solids generated by wipers and 15% to 25% of the total solids generated by dust mops. A series of suspended solids analyses for coveralls indicated about 1.1 kgs of suspended material generated per 100 kgs. laundered, as compared to 5.8 kgs for a similar set of analyses for print wipers.

Figure 20 demonstrates the wastewater quality variability with time at the sewer discharge of this laundry. Time zero indicates the time at which the sampling commenced. The drastic fluctuations observed at the industrial laundry were not as evident for this discharge, due to the fact that it is somewhat weaker (see Figure 2, 3, and 4). Suspended solids did not vary significantly, and were always less than 1,000 mg/l. The variability of this discharge would not have as adverse an effect on wastewater treatment as the industrial laundry wastewater variability. However, there is enough fluctuation to make equalization desirable. The fluctuation may also be more pronounced if more samples were taken or if the tests were repeated on a different day.

BENCH SCALE FLOTATION TESTING

Analyses of two full shift composite samples obtained at the laundry are presented in Table 55. These samples demonstrate a relatively potent laundry wastewater; more potent than indicated by the uniform analysis of Table 54. The samples had the same physical appearance as the industrial

TABLE 53

WASTEWATER QUALITY OF FINAL RINSES FOR VARIOUS LAUNDERED ITEMS AT THE ROSCOE UNIFORM LAUNDRY

Article Laundered	pH Units	TOC mg/l	Suspended Solids-mg/l	Total Solids mg/l
Uniforms	9.5	57	176	360
Shirts	10.05	64	126	524
Pants	10.2	79	110	534
Coveralls	9.7	67	128	469
Uniforms	9.5	64	60	374
Entrance Mats	10.6	373	385	1,093
Shirts	10.1	66	86	460
Print Rags*	9.3	378	240	633

* After 13th rinse; rest of items had only 6 to 7 rinses.

TABLE 54

ESTIMATED WASTE LOAD QUANTITIES FROM UNIFORM LAUNDERING OPERATIONS

Article Laundered	kgs TOC/100 kgs of Article Laundered	kgs Total Solids/100 kgs Article Laundered
Shirts	2.25	11.36
Print Rags	11.54	20.91
Uniforms	2.47	6.89
Shirts	2.53	9.23
Pants	2.34	8.90
Coveralls	1.73	6.91
Uniforms	0.87	6.80
Entrance Mats	9.94	22.39

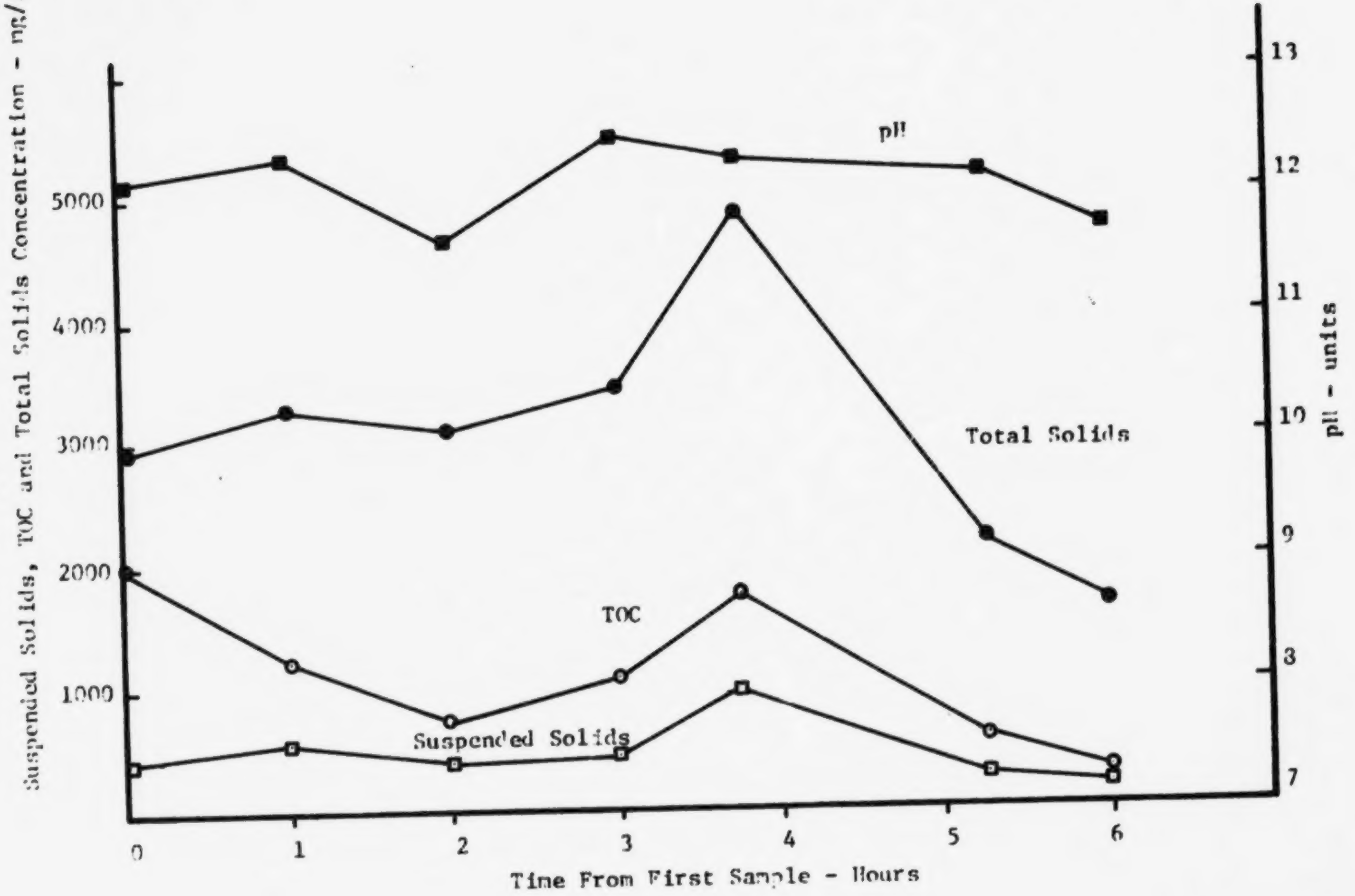


FIGURE 20

VARIABILITY OF WASTEWATER QUALITY WITH TIME AT THE SEWER DISCHARGE FOR A UNIFORM LAUNDRY ON 5/24/72

TABLE 55

COMPOSITE WASTEWATER ANALYSES OF UNIFORM LAUNDRY WASTEWATER ON MARCH 23 and 24, 1972

Analysis	3/23 Composite	3/24 Composite
Total Solids, mg/l	3,845	3,053
Total Volatile Solids, mg/l	2,153	1,469
Suspended Solids, mg/l	685	425
Volatile Suspended Solids, mg/l	565	365
pH, units	11.9	11.8
Alkalinity, mg/l as $CaCO_3$	1,272	1,230
Grease, mg/l	734	340
TOC, mg/l	1,832	1,349
BOD, mg/l	608	534
Soluble BOD, mg/l	147	203
Copper, mg/l	1.8	2.3
Iron, mg/l	16.3	14.5
Chromium, mg/l	2.4	1.4
Lead, mg/l	9.8	6.8
Mercury, µg/l	1	3
Cadmium, mg/l	<0.01	<0.01
Zinc, mg/l	3.4	3.8
Cyanide, mg/l	0.7	0.36
Phenol, mg/l	0.5	1.2

laundry wastewater composites. If it is assumed that 6,800 kgs of uniforms are laundered and produce 2.5 kgs of TOC per 100 kgs cleaned and 8.0 kgs of total solids per 100 kgs cleaned in 302 cu m (80,000 gal.) of wastewater; a wastewater TOC concentration of 562 mg/l and a wastewater total solids concentration of 1,800 mg/l are predicted. This is considerably lower than the 1,400 to 1,800 mg/l TOC and 3,000 to 3,800 mg/l total solids concentrations actually measured. Evidently, the print rags and entrance mats are contributing a large portion of the contamination to the wastewater, since more total solids and TOC are associated with these items. It is also likely that the majority of the heavy metals are associated with the print wipers. Table 56 aptly demonstrates that this is the case. The suds operation of two print wiper wash cycles were analyzed for various constituents, and it was found that there was enough lead in suds sample 2 to contribute 25% to 40% of all the lead found in the composites, *i.e.*, one machine dump or 1/2 of 1% of the total plant flow can contribute 40% of the lead to the effluent. It may also be noted that very high levels of chromium, zinc, and copper are also present. In a case like this, a significant reduction in effluent heavy metals could be affected by no longer laundering these types of articles. For a plant in which this type of article makes up only a small portion of its business, an economical solution to the waste problem would be elimination of the laundering of this article. This may shift the disposal problem elsewhere, or it may force the industry involved to resolve the problem by changing their practices. In either case, the handling of the heavy metals problem would be more practical elsewhere.

Table 56 gives evidence that the printer's towels dominated this wastewater and contributed excessive quantities of grease, TOC, and heavy metals. Thus the effluent composites did not reflect a pure uniform laundry wastewater. In spite of this, the wastewater total solids, TOC, BOD, grease, and suspended solid contents were still considerably lower than were those composites reported in Table 3 for industrial laundry wastewater. Therefore, this wastewater would not be expected to generate as much sludge as the industrial laundry wastewater.

Bench scale flotation tests were performed on both of the composite samples obtained, the results of which are presented in Table 57. It can be seen that reductions in suspended matter, TOC, grease, and heavy metals were affected. Calcium chloride treatment provided effective flocculation, and solids rise rates comparable to industrial laundry wastewater bench tests results were obtained. Flotation solids separation for uniform wastewater was feasible. Good reductions of almost all contaminant concentrations were obtained. TOC and suspended solids removals of 80% were similar to those obtained for the industrial laundry wastewater. All heavy metals measured were removed to a large degree, as is the case for industrial laundry wastewater treatment. It was concluded that the treatment system presently employed at the Roscoe industrial towel plant would be applicable to this plant's wastewater, as well as uniform wastewater by itself. It is generally acknowledged that the same type of wastewater would be obtained without the printer's towel contaminant contribtuion, only of a lower strength. Consequently,

TABLE 56

ANALYSIS OF PRINT WIPER SUDS AT THE ROSCOE UNIFORM LAUNDRY ON MARCH 24, 1972

Analysis	Sample 1	Sample 2
Mercury - μg/l	14	14
Zinc - mg/l	7.2	8.0
Copper - mg/l	31	6.8
Chromium - mg/l	13.6	124
Lead - mg/l	79	513
Total Solids - mg/l	20,504	32,107
TOC - mg/l	51,000	32,400
pH - units	13.0	12.7
Suspended Solids - mg/l	5,500	10,900
Grease -mg/l	11,829	22,305

TABLE 57

RESULTS OF BENCH SCALE FLOTATION TESTS OF UNIFORM LAUNDRY COMPOSITE SAMPLES OF MARCH 23 and 24, 1972

Test No.	1	2	3
Waste Used	3/23/72	3/24/72	3/24/72
Chemical Treatment:			
$CaCl_2 \cdot 2H_2O$ (mg/1)	2,000	2,000	2,000
Na_2CO_3 - mg/1	--	1,000	--
Polyelectrolyte	2 mg/1 Hercofloc 905N	2 mg/1 Nalco 675	2 mg/1 Nalco 675
Mix Time, min.	0.25	0.25	0.25
Flocculation Time, min	2	2	2
Recycle Rate, %	33	33	33
Detention Time, min	8	8	8
Rise Rate, mpm	0.18	0.28	0.34
Scum Volume, 1/1000 1	97	105	90
Sludge Volume, 1/1000 1	trace	trace	trace
Effluent Quality:			
pH, units	11.5	11.5	11.5
Suspended Solids, mg/1	155	27	154
Grease, mg/1	118	72	91
Total Solids, mg/1	2,631	3,015	2,891
TOC, mg/1	332	305	338
Copper, mg/1	0.6	0.4	0.5
Iron, mg/1	0.7	0.3	0.4
Lead, mg/1	1.1	0.4	0.8
Zinc, mg/1	0.24	0.05	0.17
Chromium, mg/1	1.7	0.8	0.8
Percent Reduction in:			
Suspended Solids	77	94	64
Grease	84	79	72
Chromium	29	43	43
Copper	67	81	79
Lead	89	94	88
Zinc	93	99	96
TOC	82	77	75

the treatment concept developed for industrial laundry wastewater should apply to uniform laundry wastewater.

UNIFORM LAUNDRY WASTEWATER TREATMENT SYSTEM EFFLUENT QUALITY

After completing the operation of the wastewater treatment system on industrial laundry wastes, the unit was operated on pure uniform laundry wastewater. This was accomplished by hauling uniforms from the Roscoe uniform laundry to the wastewater treatment site and laundering the uniforms in the linen washing machines shown in Figure 1. This task was performed in a manner that would cause as little interference as possible in the laundry's normal work schedule and operation. The water discharged from the uniforms went directly to the equalization pit from where it was pumped back to the treatment system. Six different uniform wastewater treatment tests were performed in this manner utilizing only the washwater from synthetic pants, synthetic shirts and coveralls.

Table C-7 of Appendix C presents the operating conditions of the wastewater treatment system for this test work. Table C-8 lists the vacuum filtration data and Table C-9 the effluent quality analyses. Each test was performed for as long a time as possible, until the equalization pit was empty of water. The February 7 run was contaminated with print wiper wastewater when the dam separating the industrial wastewater from the uniform wastewater failed. Only limited analyses were performed for this test. Two sets of operating conditions are presented for February 13, but sample analyses were performed for only the second test. February 13 was also the wastewater reuse test. Heavy metal analyses were made for the February 6 and February 13 tests. All samples analyzed were composites for the length of the test. The raw wastewater and scum were composited manually, while all other samples were composited automatically.

The unit was operated at a widely varying set of conditions; but no reasonable trends or correlations were demonstrated between suspended solids removal rates and calcium chloride dosage, recycle ratio, surface overflow rate, or mass loading. These independent variables also did not correlate with grease removal rates or effluent suspended solids. This is due in part to the limited amount of data, and to the varying wastewater quality. It may also be noted that the equalization pit was not cleaned prior to the start of the uniform testing. Thus some grease and solids may have been picked up in the pit during the initial tests. Since all but one raw wastewater sample was obtained for water going to the pit, the analyses would not reflect this.

The percentage grease removal increased relatively progressively with test date, from 0% to 40% for all tests. Scum samples analyzed for grease indicated that grease or hexane soluble separation was occurring in the flotation system. Table C-8 of Appendix C shows scum grease contents varying from 834 mg/l to 10,134 mg/l. On both days, February 2 and 6, 1973, demonstrating zero grease removal, the scum samples contained 2,000 mg/l grease. Evidently, the uniform wastewater was picking up some particulate grease from the equalization pit, which was then separated in the flotation tank. The one test, February 7, where raw wastewater was obtained coming from the pit contained 1,888 mg/l grease. This was the test suffering from print wiper contamination, but it may also reflect some pickup of grease from the equalization pit. In any case, the influence this may have had on the performance of the flotation unit is unknown at this time. Consequently, only the average wastewater quality will be discussed as was done for the industrial wastewater. The February 7 analyses will not be included in the discussion due to the printer's towel contamination.

Table 58 presents the average wastewater qualities for the various treatment system points for all the data presented in Table C-9 of Appendix C. The numbers in parentheses beside each average value indicates the number of data points that the average represents. Table 59 presents the ranges of values for those averages representing more than two numbers.

From both Table 58 and Table 59, it is evident that the flotation unit is removing little organic matter, as determined by flotation effluent and raw wastewater samples obtained prior to the equalization pit; either measured as BOD, TOC, or grease. The samples thus do not reflect any settling or resuspension that may have occurred in the pit, and this may have influenced the results. However, it would appear from this data that the majority of the organic matter obtained from the uniforms must be soluble, and not amenable to reduction by a solids separation device. Calcium chloride treatment and solids separation did not affect a significant reduction in grease. The levels of TOC, BOD and hexane solubles measured were considerably lower than those measured for either the industrial laundry wastewater or the composite obtained at the Roscoe uniform plant (see Table 55). Thus the printer's towels were contributing much organic matter to the composites obtained at the uniform laundry. It may be noted that the February 13 test utilizing the DE filter produced an excellent effluent quality affecting a 46% reduction in BOD and a 58% reduction in TOC and an effluent grease concentration of 26 mg/l. It is apparent that the DE sorbed out the grease that could not be removed in the flotation unit. The reduction of the grease caused a corresponding drop in BOD and TOC. Evidently, for the type of organic matter and hexane soluble material present in uniform wastewater, DE filtration is necessary to reduce the grease concentration to acceptable levels, i.e., 100 mg/l. This is necessary to insure that this level is met 100% of the time. Other types of filtration such as sand or mixed media do not readily absorb emulsified grease.

Due to the above observations concerning grease removal, it is appealing to consider only utilizing DE filtration for this type of wastewater. This would provide adequate grease removal, but the presence of 1,000 mg/l suspended solids would lead to quick plugging of any DE filtration system. Consequently, a preliminary solids separation device is necessary to remove the majority of the suspended material prior to the DE filter. The flotation unit did this nicely removing an average of 71% of the suspended material and providing an effluent with less than 250 mg/l suspended solids at all times. This is desirable to prevent using a lot of expensive diatomaceous earth. That the DE filter does not plug up fast is

TABLE 58
AVERAGE WASTEWATER QUALITY FOR UNIFORM LAUNDRY WASTEWATER TREATMENT

Parameter	Average Value	Flotation Effluent Average Value	Diatomaceous* Earth Effluent	Average Flotation Percent Removed	Percent* System Removed
BOD, mg/1	297 (4)	288 (4)	124	7.0 (4)	45.6
TOC, mg/1	553 (5)	474 (5)	225	13.2 (5)	58.3
Total Solids, mg/1	4,215 (5)	5,663 (5)	4,443	--	--
Volatile Total Solids, % of Total Solids	30.8 (5)	15.6 (5)	17.0	--	--
Suspended Solids, mg/1	1,003 (5)	169 (5)	30	70.8 (5)	96.6
Volatile Suspended Solids, % of Suspended Solids	49.0 (5)	70.4 (5)	90	--	--
Grease, mg/1	234 (5)	190 (5)	26	17.1 (5)	92.0
Copper, mg/1	4.4 (2)	0.42 (2)	0.1	72.6 (2)	98.7
Lead, mg/1	5.1 (2)	1.3 (2)	0.9	74.1 (2)	86.2
Mercury, μg/1	3.6 (2)	0.7 (2)	0.6	79.6 (2)	86.0
Cadmium, mg/1	0.14 (2)	0.015 (2)	0.02	89.5 (2)	86.7
Zinc, mg/1	7.0 (2)	0.54 (2)	0.03	92.3 (2)	99.5
Chromium, mg/1	0.88 (2)	0.14 (2)	0.11	62.3 (2)	93.1
Nickel, mg/1	1.0 (2)	1.0 (2)	0.7	5.0 (2)	30.0
Iron, mg/1	46.5 (2)	1.4 (2)	0.8	96.1 (2)	98.9
Alkalinity to pH 8.3, mg/1 as $CaCO_3$	623 (5)	259 (5)	110	--	--
Alkalinity to pH 3.7, mg/1 as $CaCO_3$	1,076 (5)	402 (5)	185	--	--

* Represents only one series of analyses.

TABLE 59

RANGES OF WASTEWATER QUALITY ENCOUNTERED IN UNIFORM LAUNDRY WASTEWATER TREATMENT

Parameter	Range Raw Wastewater Values	Range Flotation Effluent Values	Range Flotation Effluent Percent Removed
BOD, mg/l	192 - 473	274 - 449	0 - 7.1
TOC, mg/l	400 - 765	335 - 570	0 - 25.5
Total Solids, mg/l	2,801 - 6,967	3,531 - 6,900	--
Volatile Total Solids, % of Total Solids	18.3 - 40.6	9.3 - 21.8	--
Suspended Solids, mg/l	316 - 1,765	67 - 243	23.1 - 95.8
Volatile Suspended Solids, % of Sus. Solids	32.8 - 73.7	46.1 - 95.5	--
Grease, mg/l	122 - 369	107 - 242	0 - 38.9
Alkalinity to pH 8.3, mg/l as $CaCO_3$	255 - 945	25 - 735	--
Alkalinity to pH 3.7, mg/l as $CaCO_3$	820 - 1,365	195 - 890	--

evidenced by the 0.5 kg/sq cm/hr (7.0 psi/hr) DE differential pressure increase during the February 13 test at a hydraulic loading of 13 lpm/sq m (0.33 gpm/sq ft). This may allow 10 hours of operation before the filter would have to be backwashed and precoated again, i.e., one full shift of operation. It is therefore desirable to keep the flotation and DE filtration modules in series as installed at the Roscoe laundry, for uniform laundry wastewater treatment.

Table 58 demonstrates that uniform wastewater contains heavy metals considerably above trace levels. The uniform wastewater contains heavy metals at about the same concentrations as the industrial laundry wastewater (compare Table 43). The industrial laundry wastewater is higher in lead and chromium, while the other metals are approximately at the same levels. Since the raw uniform wastewater samples were obtained prior to the pit, no heavy metal contamination of the uniform samples can be attributed to this source. Therefore, the conclusion drawn is that uniforms are a significant source of heavy metals at this particular laundry. It is difficult to say what the exact source of the heavy metals might be, due to the many clients and diversified number of industries that utilize the laundry's service. It is probable that this problem is prevalent at many laundries handling uniforms used at service stations or in metal products manufacturing.

From Table 58 it is evident that the uniform wastewater treatment system readily separated all heavy metals measured except nickel. Copper, lead, mercury, cadmium, zinc, chromium and iron were all effectively reduced in the flotation and DE filtration steps. The removal mechanism is the same as previously discussed for industrial laundry wastewater treatment: Solids separation at a high pH was useful in causing a reduction in heavy metals.

UNIFORM LAUNDRY WASTEWATER TREATMENT SYSTEM OPERATIONAL RESULTS

The mechanical operation of the uniform laundry wastewater treatment system was good for all six days of testing. The flotation system separated large amounts of gray solids concentrating them to 0.5% to 3% suspended solids, the entire range of which proved suitable for vacuum filtration. The solids generated were those present in the laundry discharge and those precipitated by the calcium chloride. Good reductions in suspended material were obtained at overflow rates of 94 lpm/sq m (2.3 gpm/sq ft) and recycle ratios of 75%. The unit could possibly have performed well at even higher hydraulic loadings, but this was the maximum output of the equalization pit return pump. Consequently, this flotation tank is rated at 541 lpm (143 gpm) for the uniform laundry wastewater treated at this facility. A lower recycle ratio may also be possible for this wastewater due to its lower solids content, with the lowest possible ratio being 50%.

Good visual flocculation was achieved at all calcium chloride dosages utilized during this test work. It was generally observable that 2,000 mg/l calcium chloride was the optimum dosage providing a very large tough floc. Two mg/l of anionic polyelectrolyte helps considerably in enlarging the floc and strengthening it.

At no time during the testing was vacuum filter blinding a problem. The sludge always readily filtered and was not sensitive to filter operating conditions. Table C-8 of Appendix C presents all the vacuum filter operating data obtained during the study. The cake would not dewater beyond 15% to 20% cake solids, as it would crack at this solids contenc and the vacuum level would decrease on the dry cycle. The filter yield obtained was found to be directly proportional to the average scum suspended solids concentration, as shown in Figure 21. This is typical of vacuum filter installations, and according to vacuum filtration theory (14). Vacuum filtration is an effective means for dewatering sludge obtained from uniform laundry wastewater. The vacuum filtrate was of as good a quality as the flotation effluent.

The DE filter test performed, as pointed out previously, was satisfactory in that it did not quickly plug, and provided effective suspended solids reduction. A body feed rate of 3.0 mg DE per mg of suspended material led to a differential pressure buildup of only 0.5 kg/sq cm/hr (7.0 psi/hr). Consequently a body feed rate of 2.0 mg DE/mg suspended solids is probably adequate for a flotation effluent containing 200 mg/l suspended solids at a filter hydraulic loading of 18 lpm/sq m (0.45 gpm/sq ft).

The optimum uniform treatment system operating conditions are presented in Table 60. The conditions of operation are generally the same as recommended for the industrial laundry wastewater treatment system, (see Table 46), except that the flotation process does not require as much effluent recycle, and can be loaded at a slightly higher hydraulic level. It would also be desirable to have a 15 minute flotation detention time for this wastewater, to allow for increased liquid solids separation. The recommended chemical treatment and vacuum filter operation are the same as for the industrial laundry wastewater. The Moyno sludge pump also caused this material to liquify requiring liquid hauling of the sludge. The DE filter recommendatons are the same as previously discussed.

Table 61 presents the general operating results of the treatment system. Approximately the same amount of flotation scum was produced as for the industrial laundry wastewater. However, the low influent suspended solids caused the low scum solids and led to fairly large final sludge volumes of high moisture content. Generally this scum did not filter as well as the industrial laundry scum as the vacuum filter produced lower yields and cake solids, due to the lower solids concentrations. This leads to more water being associated with the sludge and consequently to higher sludge volumes per unit mass of solids. It may be feasible that a larger flotation unit providing more detention time would allow the scum to thicken to a higher concentration and provide enough reduction in sludge volume to offset the cost of the larger flotation unit. Generally 11 to 15 liters of sludge/1000 liters of raw flow were produced, based on a sludge density of 1.077 gm/cc (9.0 lb/gal.).

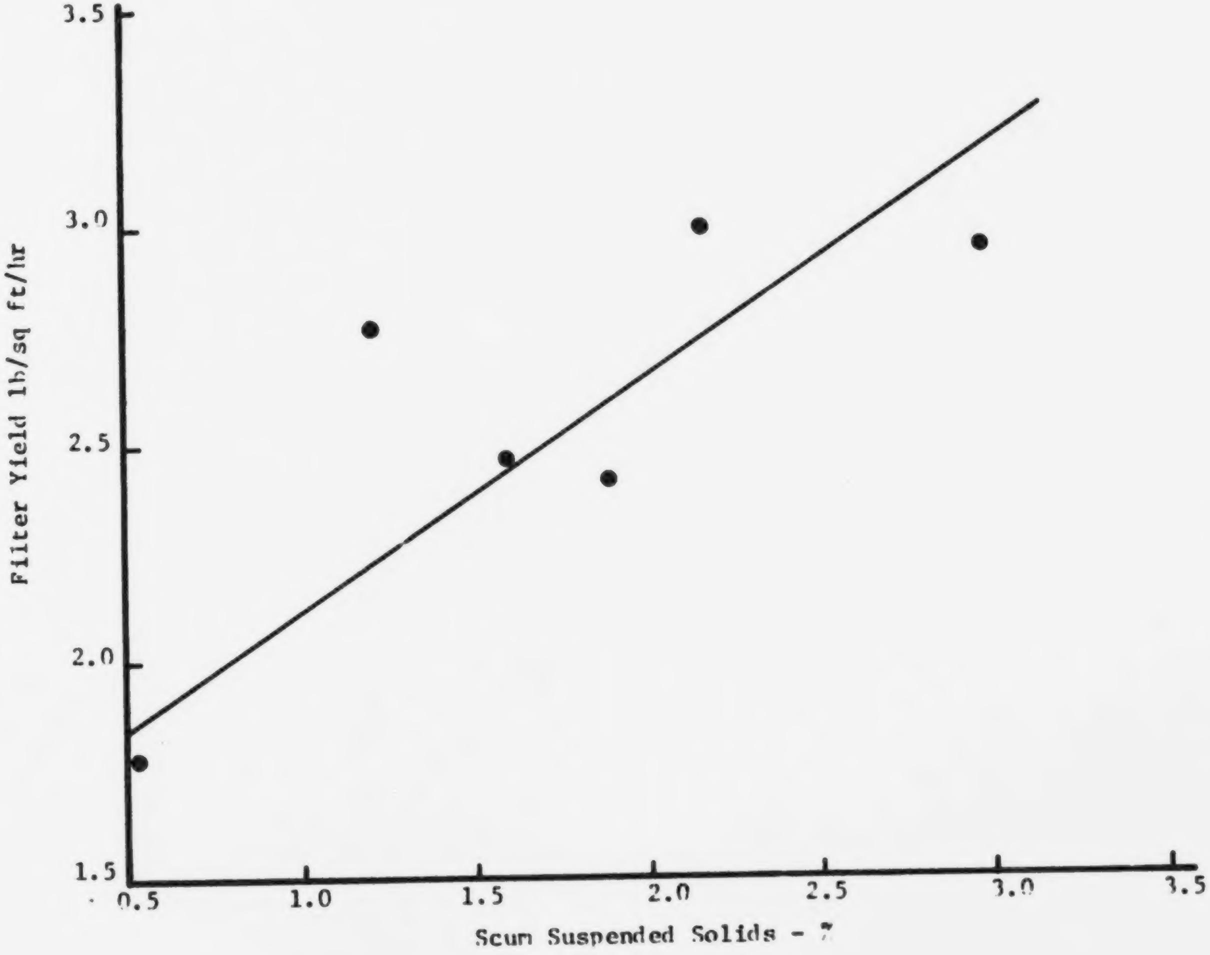


FIGURE 21
VARIATION OF FILTER YIELD WITH UNIFORM FLOTATION SCUM SOLIDS

TABLE 60

GENERAL OPTIMUM OPERATING CONDITIONS FOR THE UNIFORM WASTEWATER TREATMENT SYSTEM

Flotation Overflow Rate	**96 lpm/sq m**
Flotation Recylce	75%
Flotation Detention Time	9.5 minutes
Equalization Time	1 hour
$CaCl_2$ Dosage	2,000 mg/l
Polyelectrolyte Dosage	2 mg/l
Detention Time Between Two Chemical Additions	1 hour
Vacuum Filter Cycle Time	5.5 minutes
Vacuum Filter Pickup Time	1.0 - 1.5 min.
Vacuum Filter Vacuum Level	**>25 cm Hg**
DE Filter Hydraulic Loading	**18 lpm/sq m**
DE Precoat	**0.73 kg/sq m**
DE Body Feed	2 parts DE to 1 part Suspended Solids

TABLE 61

GENERAL OPERATING RESULTS OF THE UNIFORM TREATMENT SYSTEM

Flotation Scum Volumes	80 to 100 1/1000 l raw flow
Sludge Volume	10 to 4 1/1000 l raw flow
Sludge Moisture	80 - 90%
Filter Yield	10 - 15 kgs/sq m/hr
Filter Blinding	0%
Vacuum Filtrate Flow	40 - 80 lpm
DE Pressure Buildup	0.5 kg/sq cm/hr

UNIFORM WASTEWATER TREATMENT SYSTEM OPERATING COSTS

Operating costs for the uniform laundry wastewater treatment operation, as obtained from the field installation are presented in Table 62. The chemical coagulant cost is based upon the addition of 2,000 mg/l calcium chloride and 2 mg/l anionic polyelectrolyte. Neutralization costs are based on neutralizing 200 mg/l flotation effluent alkalinity as calcium carbonate with sulfuric acid. Unit chemical costs are \$5.17/kg (\$2.35/lb) for the polyelectrolyte \$0.088/kg (\$0.04/lb) for sulfuric acid, and \$0.102/kg (\$0.0465/lb) for calcium chloride. Power costs and material and maintenance costs are the same as for industrial laundry wastewater treatment. Diatomaceous earth costs are based on the addition of 0.477 grams (4 lbs per 1000 gal.) of DE per 1 liter of wastewater. Sludge disposal costs are \$0.012/liter (\$0.045/gal.), based on an average of 13 liters of sludge per 1000 liters of wastewater treated (See Table 48).

Capital costs are based on the same conditions utilized for the industrial laundry wastewater. The unit costs are lowered because of the greater capacity of the flotation tank for uniform laundry wastewater. For a two shift operation, the amortization cost would be 4.7¢/cu m (18¢/1000 gal.) wastewater and 3.2¢/cu m (12¢/1000 gal.) wastewater for a three shift operation. The same observations made for the industrial laundry regarding capital costs hold true for uniform laundries. The total operating cost was then 66.8¢/cu m (\$2.53/1000 gal.) treated at this laundry with the costs reduced to 60.4¢/cu m (\$2.29/1000 gal.) if chemicals are handled in bulk rather than by hand.

Thus, it is evident that even the weaker uniform wastewater costs a considerable amount to treat. However, the nature of the wastewater, its grease content (>100 mg/l) and heavy metal content, make treatment imperative in urban areas. The operating costs presented here would be expected to vary from laundry to laundry dependent on sludge handling methods, wastewater flow rate, chemical treatment methods, wash load mix, etc. Each laundry will have to determine its own costs dependent on its own situation.

UNIFORM LAUNDRY WASTEWATER REUSE TESTING

The February 13 wastewater DE effluent was used in a water reuse test to wash a load of synthetic pants. The test was performed in the same manner as the reuse test for industrial wipers, except no control samples of machine dumps were obtained. Analyses for the carryover and fifth rinse operations were performed to determine if the discharged water was significantly poorer in quality than that obtained from the industrial laundry survey performed on March 24, 1973, when softened city water was used to launder the same items. Table 63 presents the results of these analyses as compared to samples obtained from a load of synthetic pants laundered on March 24, 1972.

As in the industrial laundry wastewater reuse test, all analyses indicate that the reused water discharge is more contaminated with organic materials and solids than the city water regularly used for washing. By the fifth rinse, the washing machine discharge is approaching the quality of the DE filter effluent of February 13, 1973.

TABLE 62

UNIFORM LAUNDRY WASTE TREATMENT COSTS IN ¢/CUBIC METER

Item	Cost
Coagulation Chemicals	22.5 (16.1)[a]
Neutralization	1.8
Sludge Disposal	15.3
Power	2.6
Material and Maintenance	6.6
Amortization - 20 years @ 6%	9.5
Diatomaceous Earth	8.5
TOTAL Cost for Sewer Disposal	66.8 (60.4)[a]

(a) If chemicals bought in bulk

TABLE 63

REUSE WASTEWATER ANALYSES

FOR TWO LOADS OF SYNTHETIC PANTS

Sample	Wash Operation	pH	TOC	Total Solids
Reused Water	Carryover	12.6	5,620	21,000
City Water	Carryover	12.7	3,520	13,429
Reused Water	fifth rinse	11.2	355	5,069
City Water	fifth rinse	11.25	214	1,145

It is obvious that reusing the wastewater will result in an increase in dissolved material in the laundry process water. From Table C-9, it is also apparent that calcium hardness is a problem, as 860 mg/l calcium was measured in the DE effluent composite. Based on the fifth rinse quality, it appears that approximately 4,500 mg/l of total solids were added to the wash water, on a once through basis. It was not possible to determine if the same amount of solids would be added, if the same water were treated and reused again. It is anticipated that the solids would keep building up at a decreasing rate until an equilibrium level was reached (1). It is obvious that the calcium hardness and dissolved solids content is going to limit the extent of wastewater reuse. This aspect is discussed in detail in Section VIII for various laundry wastewater types. Both process feasibility and economics are included in the discussion.

The laundry personnel at the plant examinated the cleaned pants and compared them to pants laundered with regular city water, and found no differences in the cleaned garments. The metal buttons on the pants showed no traces of grease smears, and neither did the metal cylinder on the wash wheel. Several people in authority examined the garments and agreed the quality of the pants had not suffered. Thus the limitations on reusing wastewater treatment system effluent for laundering uniforms lies not with degrading the uniforms, but in providing a suitable water quality.

UNIFORM LAUNDRY WASTEWATER TREATMENT SYSTEM PROCESS EVALUATION AND APPLICABILITY

Due to the similarity of the uniform laundry and industrial laundry wastewater characteristics, the observations made for industrial laundry wastewater treatment regarding supplies, biological treatment methods, wastewater variability from laundry to laundry, and general design philosophy hold true here also. The presence of heavy metals at the levels encountered, notably lead, zinc, and copper makes wastewater treatment a necessity rather than an economic alternative. Hexane soluble and alkalinity concentrations are also problems that must be dealt with. The treatment system utilized for the Roscoe uniform wastewater demonstrated that all sewer standards can be met by flotation, diatomaceous earth filtration waste treatment. It was evident that the flotation process by itself would not do the required treatment job.

If heavy metals are the major problem at the uniform laundry, it will be necessary to perform pilot plant studies at that laundry, because of the complexity of the problem and the need for determining the consistency with which the particular metallic components under consideration are removed. If heavy metals are not a problem at the uniform laundry, the treatment system can be sized from appropriately obtained composite samples and bench scale testing. This is true of those laundries where the main problems are suspended solids and hexane solubles.

When heavy metals are a problem, the laundry owner may consider changing his supplies to the caustic-silicate formula Roscoe utilizes so that calcium chloride will provide the treatment required at an alkaline pH.

If the metals were to be removed by ion exchange, reverse osmosis, or other sophisticated techniques, a relatively suspended solids free water must be supplied for these systems. Thus the diatomaceous earth effluent would go to a heavy metals separator and add considerably to the treatment cost. It is much cheaper to remove the metals in a suspended solids separator. Likewise, any change in the calcium chloride treatment technique, e.g., to alum, would result in a relatively nondewaterable scum. Consequently, expensive precoat vacuum filtration would have to be used to reduce sludge volumes; or a much larger volume of liquid waste, the scum itself, would have to be hauled away (15). Either technique would result in a significantly higher cost than the 60.5¢/cu m ($2.29/1000 gal.) of wastewater presented here. Thus a change in the wash formula in a case like this can prove economical. The full justification for such a move could only come from laboratory testing and the laundries' own situation.

The economic considerations for uniform laundries are similar to the industrial laundry situation. A capital outlay of at least $40,000 will be required for a medium sized uniform laundry with a minimum of $100 per shift operating costs. Treatment of uniform wastewater is not a profitable picture either, though better than for those laundries cleaning shop towels. In all cases, either reduced profits or price increases are going to be involved. The unit price for washing uniforms would increase 1.1¢ to 2.2¢ per kilogram (0.5 to 1.0¢/lb) laundered if one figures that approximately 33.3 liters of wastewater are treated for each kilogram (4 gals./lb) of uniforms laundered after allowing for evaporative losses. The treatment cost for the Roscoe plant would be 1.9¢/kg ($.0085/lb) for their laundered uniforms. The alternatives of treatment versus other measures can be determined on a product unit cost basis.

More information is needed on the variation in quality of uniform laundry wastewater so that more concrete economic alternatives than the above can be formulated. Information on the economic considerations of changing the laundry supply system to be compatible with the treatment unit is also required. This study has demonstrated that uniform laundry wastewater can be treated effectively, but information on the variety of uniform laundry wastewater characteristics is required in order to determine the degree of applicability of the treatment system. It is likely that the flotation-filtration system will be applicable in most cases, but the chemicals, size, and operating costs may vary significantly with wastewater quality.

SECTION VII

LINEN LAUNDRY WASTEWATER TREATMENT

LINEN LAUNDRY WASTEWATER QUALITY

A linen laundry wastewater survey was performed at the same Roscoe laundry where the treatment system existed. Those three machines at the Roscoe laundry washing linens were utilized for the survey work. This was logical since these linen wastes would be the ones treated by the demonstration unit. The survey was performed on May 19 and 20, 1971. Grab samples were obtained from each washing machine dump for the entire washing cycle for continuous towels, kitchen towels, tablecloths, and napkins to characterize the wastewater emanating from these articles. It was hoped that a composite sample of linen wastewater could also be obtained. However, because the linen machines discharge into the same channel as the industrial washing machines, the wiper and dust mop wastewater often backed up into the linen area making it difficult to obtain a composite sample of only linen wastewater. Therefore, grab samples were obtained from the linen flow when it appeared that it was not contaminated by industrial wastewater, and later composited for bench scale treatment tests.

All samples were analyzed for total solids, total organic carbon, and pH. Other samples were analyzed for suspended solids and alkalinity. Bench scale chemical treatment tests were performed on the grab samples to define the effect of linen wastewater variability on the chemical treatment process.

The supplies used for the linens include an anionic detergent and a tallow soap with a titer of 40-42 for removing the soil. The base oil emulsifier used for the wipers and uniforms is also added to the linen wash cycle, though in lesser quantities. These supplies are added to each of two suds operations or breaks. Bleach is added as sodium hypochlorite or isocyanuric acid. The last cycle has ammonium silicofluoride added for pH adjustment and a chlorohydrocarbon mildicide added. Starch is added to the sour operation when it is required. The detergent utilized was of the caustic silicate variety, so that this wastewater also contains a lot of dissolved silica.

The results of a typical series of analyses for a 364 kg (800 lb) load of kitchen towels and a 136 kg (300 lb) load of tablecloths are presented in Tables 64 and 65 respectively. From these tables it can be seen that the concentration of solids and TOC decreases with the second flush and increases dramatically after the addition of supplies. The total solids and TOC concentrations then decrease again followed by another increase in TOC with the high suds cycle. The concentrations of each then decrease gradually with each succeeding rinse. This pattern was followed for all the articles sampled.

From these tables it is evident that linen wastewater is not nearly as potent as industrial laundry wastewater. It appears to be of about the same level of contamination as uniform laundry wastewater. It may be noted that linens are utilized for considerably dfffererent purposes than shop towels or uniforms. The linens washed at this laundry are utilized mainly by food handling industries; restaurants or butchers, and for restroom cleanliness, i.e. continuous towels. Thus the type of soil present in linen items is considerably different than that in uniform or industrial items. Even though the levels of gross chemical properties for uniform and linen laundry wastewater may appear relatively the same, i.e. TOC, total solids, suspended solids, the wastewater treatment characteristics and chemical properties of the two wastewaters may be considerably different. These tables also demonstrate extreme variability of wastewater quality even for linen laundries. The data obtained from the analyses of the machine dumps were used to compute the kgs of TOC and total solids in the wastewater per 100 kgs of articles washed, including the supplies. The results of these computations are presented in Table 66 along with all the other similar analyses presented in the industrial and uniform laundry sections. All data obtained from this survey and the uniform survey are presented in this table, while only the ranges for the industrial items are given. Complete data for all linen dumps sampled and analyzed may be found in Table C-3 of Appendix C.

From this table it can be seen that there is not much difference in the amounts of TOC and total solids generated by the different linen articles. The kitchen towels contribute the most to the wastewater contamination. In comparison with the industrial articles, it can be seen that the quantity of TOC and total solids generated by 100 kgs of linen or continuous towels is only about 10% of that generated by the wipers. This, in conjunction with the low proportion of flow generated by the linen washing machines at the Roscoe plant demonstrates what a minor contribution the linen flow makes to the pollutional load of the final sewer discharge. The effect of the linen wastewater on the plant discharge is minimal. Generally, this table shows that synthetic shirts and pants and uniforms contribute about the same amount of TOC and total solids to the wash water as kitchen towels and heavy soil table linens. The uniforms contribute more TOC and solids than do the

TABLE 64

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION FOR A 364 KG LOAD OF KITCHEN TOWELS

Operation	TOC (mg/1)	Total Solids (mg/1)	pH (Units)	Suspended Solids (mg/1)
Flush	1,296	3,211	7.5	--
Flush	480	1,083	8.6	360
Suds	3,030	8,004	12.6	1,895
Rinse	448	3,098	12.3	380
High Suds	1,140	2,944	12.05	745
Bleach	600	2,115	10.8	430
Rinse	164	714	10.1	110
Rinse	92	426	9.7	102
Rinse	44	334	9.4	43
Rinse	156	343	9.0	85
Sour	10	337	4.6	90

TABLE 65

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION FOR A 136 KG LOAD OF TABLECLOTHS

Operation	TOC (mg/1)	Total Solids (mg/1)	pH (units)
Flush	445	1,034	5.85
Flush	435	865	6.4
Break	2,555	9,548	12.3
Carryover	1,550	6,341	12.35
Suds	2,012	6,638	12.0
Rinse	740	2,600	11.8
Bleach	952	2,726	11.9
Rinse	329	1,276	11.25
Rinse	268	668	10.7
Rinse	150	483	10.1
Rinse	107	374	9.9
Sour	54	801	4.5

TABLE 66

ESTIMATED WASTE LOAD QUANTITIES FROM VARIOUS LAUNDERED ITEMS

Article Laundered	Kgs TOC per 100 Kgs of Article Laundered	Kgs Total Solids/100 Kgs Article Laundered
Shirts	2.28	11.36
Print Rags	11.54	20.91
Uniforms	2.47	6.89
Shirts	2.53	9.23
Pants	2.34	8.90
Coveralls	1.73	6.91
Uniforms	0.87	6.80
Entrance Mats	9.94	22.89
Continuous Towels	1.6	6.8
Table Linen	0.5	2.35
Table Linen	0.9	4.9
Kitchen Towels	2.85	9.27
Kitchen Towels	1.45	4.95
Kitchen Towels	2.3	8.9
Table Linen	2.44	8.08
Napkins	0.8	4.4
Table Linen	1.6	6.2
Print Wipers	18-42	48-66
Dust Mops	12-13	40-41
Machine Wipers	24-45	65-73

lighter soil napkins and continuous towels. Neither type of article contains near the level of contamination of the industrial laundry articles.

A series of suspended solids analyses on each individual dump of a load of kitchen towels indicated that 1.1 kgs of suspended matter/100 kgs of kitchen towels washed were produced. A similar series of analyses on a load of print wipers demonstrated that about 5.8 kgs of suspended solids/100 kgs of print wipers washed were produced. Thus the non-industrial articles are contributing only about 1/5 of the suspended solids generated by an equivalent weight of wipers. A similar set of analyses for a load of coveralls also measured 1.1 kgs of suspended solids per 100 kgs of coveralls. Thus the uniform wastewater generated an amount of suspended matter comparable to the kitchen towels, again demonstrating that there is not a gross difference between the amount of organic solid contaminants added to the wash water by uniforms and linens. Consequently, one would expect that the variability of linen wastewater at the sewer discharge point would be similar to that for uniforms (see Figure 20).

BENCH SCALE FLOTATION TESTING OF LINEN LAUNDRY WASTEWATER

The linen grab samples obtained were composited in equal volumes to simulate a representative sample of linen waste. A series of grab samples from each washing cycle of a load of kitchen towels was also composited in proportion to the volume of water utilized per wash operation to simulate a linen sample. Several days after obtaining the samples, they were subjected to chemical treatment tests to determine what dosages and chemicals were required to promote floc formation to make the waste amenable to flotation. The waste characteristics of the two samples are presented in Table 67. It was found that $CaCl_2 \cdot 2H_2O$ treatment was ineffective on the two composite samples. However, alum and sulfuric acid proved to work quite well for the composited grab samples. By adjusting the initial pH to 9.5 with sulfuric acid followed by 800 mg/l alum and 2 mg/l Purifloc N-11 (nonionic polyelectrolyte), a good floc was formed. The kitchen towel composite needed no pH adjustment as 800 mg/l alum and 2 mg/l Purifloc N-11 formed a good floc. The final pH's of the treated samples were 5.0 to 5.2.

Two bench scale flotation tests were performed on the composited grab samples obtained from the linen discharges in the trench. The results of these are presented in Table 68. It can be seen that the results were not too good for this particular sample. Increasing the alum dosage improved the results somewhat. The flotation effluent was a cloudy white and was slightly better than had been experienced for uniforms (see Table 57).

TABLE 67

WASTE CHARACTERISTICS OF LINEN COMPOSITES OF MAY 20, 1971

Analysis	Composite of Linen Grab Samples	Composite of Kitchen Towel Grab Samples
Total Solids, mg/l	2,160	1.752
Suspended Solids, mg/l	346	288
pH, units	11.3	10.2
Silica as SiO_2, mg/l	510	--
Alkalinity as $CaCO_3$, mg/l	665	--
TOC, mg/l	548	--
Volatile Total Solids, mg/l	1,106	--
Volatile Suspended Solids, mg/l	330	- -
Grease, mg/l	203	--

TABLE 68

BENCH SCALE FLOTATION TESTS CONDUCTED ON LINEN COMPOSITE SAMPLE OF MAY 20, 1971

Chemical Treatment	Test No. 1 343 mg/l H_2SO_4 800 mg/l Alum 2 mg/l Purifloc N-11	Test No. 2 294 mg/l H_2SO_4 1,200 mg/l Alum 2 mg/l Purifloc N-11
Recycle Rate, %	50	50
Rise Rate, mpm	0.09	0.24
Detention Time, min	8	8
Scum Volume, 1/1000 l	40	50
Sludge Volume, 1/1000 l	Trace	-
Effluent Quality		
pH	5.2	5.6
Suspended Solids, mg/l	236	129
% Suspended Solids Removal	31.8	62.5
Total Solids, mg/l	1,853	1,798
Volatile Total Solids, mg/l	506	450
TOC, mg/l	215	153
% TOC Removal	62.5	72
Grease, mg/l	98	--
% Grease Removal	51.8	--

The effluent from test number two was filtered through diatomaceous earth to determine what final effluent quality might be expected. These results are presented in Table 69. Compared to the final rinse qualities of various linen articles laundered in the survey, it is apparent that this treatment produced a good quality effluent. The final rinses of the linen wash load samples had between 85 and 440 mg/l suspended solids, and 23-229 mg/l TOC, and 300-824 mg/l total solids. The bench scale diatomaceous earth treated flotation effluent thus compares favorably with the final rinses except for the parameter of total solids. Thus, alum coagulation and DE filtration appeared very promising for the Roscoe linen wastewater.

Prior to the start of full scale linen laundry wastewater treatment in 1973, fresh linen samples were obtained on January 10, 1973 for more bench scale test work to insure that the treatment characteristics of the linen wastewater had not changed. Two 11 liter(3 gals.) composite samples of linen waste were obtained by compositing wastewater from one entire wash cycle of one 364 kg (800 lb) washer. The two samples represented wastewater from washing tablecloths and kitchen towels respectively. Bench scale chemical treatment tests were performed in the field to insure that the chemical treatment characteristics would be representative of what actually happens in a treatment system.

Various combinations of sulfuric acid and alum were tried on the fresh samples of linen waste obtained on 1/10/73. In all cases, treatment was poor. Best results obtained when treating with alum were achieved with no acid and 3,000 mg/l alum. This was considerably different than what had been determined in 1971. Treatment with calcium chloride and Purifloc A23 produced better results than alum. About 1,000 mg/l $CaCl_2 \cdot 2H_2O$ was the optimum dosage for the table cloth waste and 2,000 mg/l was the optimum dosage for the kitchen towel wastewater. Five mg/l Purifloc A23 was needed to form a large strong floc. Chemical treatment tests were performed again on the same samples two days later at the Environmental Sciences Division laboratory. At that time, treatment with acid and alum appeared to be somewhat improved while treatment with calcium chloride appeared to be slightly less effective. Chemical treatment tests were again performed on the same waste samples on January 17, 1973. The aged tablecloth waste could now be treated with alum quite well. Treatment of the kitchen towel waste with acid and alum appeared to be somewhat better than before, but the improvement was not as great as with the tablecloth waste. Treatment of the aged waste with calcium chloride appeared to be the same or slightly worse than treatment of the fresh waste. It was now apparent that the age of the waste significantly affected the chemical coagulation and flocculation properties of the wastewater.

A comparison of the analysis of the January 10, 1973 samples with the analyses of linen wastes tested previously is shown in Table 70. The initial work on treating linen wastewater was performed on 8 samples

TABLE 69

WATER QUALITY OF DIATOMACEOUS EARTH FILTERED LINEN FLOTATION EFFLUENT AS COMPARED TO LINEN FINAL RINSE QUALITY OF MAY 20, 1972

Analysis	Bench Scale Effluent	Final Rinse
pH	5.6	8.6-10.4
Suspended Solids, mg/l	16	85-440
% Suspended Solids Removal	87.7	--
TOC, mg/l	74	23-220
% TOC Removal	51.6	--
Total Solids, mg/l	1,499	300-824
Volatile Total Solids, mg/l	335	--
Volatile Suspended Solids, mg/l	5	-

TABLE 70

COMPARISON OF LINEN WASTEWATERS OBTAINED ON VARIOUS DATES AND FROM VARIOUS LAUNDRIES

Type of Work					Kitchen Towels	Table Cloths	Kitchen Towels	Table Cloths
Laundry	American Linen Supply			Cosmopolitan	Roscoe GC	Roscoe GC	Roscoe GC	Roscoe GC
Date	1969			1969	1971	1971	1973	1973
	Min.	Max.	Avg.					
pH	10.3	11.2		11.1	10.2	11.3	11.4	11.6
Alk., mg/1 $CaCO_3$	500	925	679	525	--	665	1525	1225
TS, mg/1	1973	3663	2675	2386	1752	2160	6514	3054
TVS, mg/1	1468	1630	1549	--	--	1106	4014	1280
TNVS, mg/1	--	--	--	--	--	1054	2500	1774
SS, mg/1	500	1474	736	611	288	346	1530	340
VSS, mg/1	--	--	--	--	--	330	1330	270
NVSS, mg/1	--	--	--	--	--	16	200	70
COD, mg/1	2125	5113	3057	2428	--	--	--	--
TOC, mg/1	--	--	--	--	--	548	2150	530
Si, mg/1 as SiO_2	--	--	--	--	--	510	940	685
Soluble Solids, mg/1	1725	2038	1837	--	1464[1]	1814[1]	4984[1]	2714[1]
Vol. Sol. Solids,mg/1	964	991	978	--	--	776[1]	2684[1]	1010[1]
Grease, mg/1	--	--	883	558	--	203	1220	276
Sol. COD, mg/1	1173	2590	1649	767	--	--	--	--
Sol. TOC, mg/1	--	--	--	--	--	--	900	330

[1] By Calculation

obtained from American Linen Supply (Milwaukee) and one sample from Cosmopolitan Laundry (Chicago) in 1969 (2). The American Linen Supply samples were tested within three hours of sampling. The Cosmopolitan sample was tested the day after sampling. Best results were obtained when treating with sulfuric acid (240 to 540 mg/l) and alum (500 to 700 mg/l as $Al_2(SO_4)_3 \cdot 18H_2O$). In May 1971, a composite sample of kitchen towel waste and one of tablecloth waste were obtained from the Roscoe Garden City Laundry. The tablecloth composite was tested several weeks after sampling. It was found that 300 mg/l sulfuric acid, 800 mg/l alum and 2 mg/l Purifloc N11 were effective in treating this sample.

The tests conducted on January 10, 1973 demonstrated that alum was not an effective coagulant for the Roscoe Garden City linen wastewater even though the previous cited test work for other laundries indicates that acid-alum chemical treatment was effective for fresh linen wastewater samples. It is not known what causes this difference, but it is suspected that it is related to differences in supplies. For fresh Roscoe linen wastewater, calcium chloride again proved to be the effective chemical coagulant. Thus when sampling linen laundries for the purpose of doing bench test work, it is necessary to perform the testing as soon as possible and to take into account the effects of the laundry wash formula on the treatment techniques. A similar set of tests for industrial laundry wastewater indicated no changes in the recommended chemical treatment techniques. Wastewater age did not appear to affect the industrial samples.

It may be noted from Table 70 that there are significant differences between the wastewater chemical analyses presented. The Roscoe kitchen towel sample is significantly higher than any of the other samples in total solids, grease, soluble solids, suspended solids, and alkalinity. This could be one reason for the differences observed in the testing. Subsequent analysis of Roscoe linen wastewater never provided linen wastewater this strong again. However, calcium chloride treatment of weaker Roscoe linen wastewater proved very effective as shown later in this report, thus indicating that waste age influences the treatability of the wastewater.

Bench scale flotation tests were performed on the two samples of January 10, 1973 using calcium chloride treatment to determine the effect of this treatment on effluent quality. The results of these tests are listed in Table 71. The addition of calcium chloride to linen waste causes a white precipitate to form. This precipitate causes a great increase in the suspended solids content resulting in a greater scum volume and slower rise rate than one might expect from the suspended solids content of the untreated waste. It should be noted, however, that there is a significant reduction in soluble solids.

TABLE 71

RESULTS OF FLOTATION TESTING OF LINEN WASTES OF 1/10/73

Waste Treated	Kitchen Towel Composite				Tablecloth Composite	
Test No.	KT-1	KT-2	KT-3	KT-4	TC-1	TC-1
$CaCl_2 2H_2O$ added, mg/l	2500	2500	2000	2500	1000	1000
Purifloc A23 added, mg/l	10	10	10	5	2	0
$Al_2(SO_4)_3 \cdot 18H_2O$ added, mg/l	--	--	--	--	--	1000
Flocculation time, min	1	1	1	1	1	1
Recycle Rate, %	50	100	50	50	50	50
Rise Rate, mpm	0.08	0.09	0.04	0.06	0.07	--
Scum Vol, 1/1000 l	202	210	278	225	75	112
Sludge Vol, 1/1000 l	trace	trace	trace	trace	trace	trace
Detention time, min	10	10	10	10	10	10
Effluent:						
Grease, mg/l	--	33	--	39	--	96
TOC, mg/l	492	456	552	498	276	240
Suspended Solids, mg/l	97	81	198	65	261	294
Total Solids, mg/l	3816	3553	3764	3866	2528	2710
Total Volatile Sol, mg/l[1]	1150	1058	1183	1158	668	588
Total Non-Vol Sol, mg/l[1]	2666	2495	2581	2708	1860	2122
Soluble Solids, mg/l[1]	3719	3472	3566	3801	2267	2416
Turbidity, FTU	62	53	130	45	230	190
Silica, mg/l as SiO_2	270	244	335	270	450	360
% Reduction in:						
Grease	--	97	--	97	--	65
TOC	77	79	74	77	48	55
Suspended Solids	94	95	87	96	23	14
Total Solids	41	45	42	41	17	11
Soluble Solids	25	30	28	24	16	11
Silica	71	73	64	71	34	47

[1] By Calculation

The results of the flotation of the kitchen towel waste were quite good affecting significant reductions in TOC, suspended solids and grease, whereas the tablecloth wastewater did not treat as well. An increase in calcium chloride dosage resulted in decreases in effluent TOC and suspended solids. The optimum calcium chloride dosage thus appeared to be 1,900 mg $CaCl_2$/l. It was concluded that calcium chloride should now be the chemical utilized in the linen wastewater treatment operation.

Afterfloc tests similar to those performed with industrial laundry wastewater were also performed with the linen laundry wastewater. The same procedures were followed. The results of the testing appears in Table 72. The testing showed that a ten minute interval between the chemical additions prevented the formation of afterfloc. Therefore, it was decided to leave the chemical addition points in the equalization pit ($CaCl_2$) and the flocculator (polyelectrolyte). This provides approximately sixty minutes between chemical additions insuring against any afterfloc formation. The treatment concept decided upon for the linen laundry wastewater treatment portion of this project was unchanged from the scheme utilized for uniform laundry wastewater treatment.

LINEN LAUNDRY WASTEWATER TREATMENT SYSTEM EFFLUENT QUALITY

The linen laundry wastewater treatment system was operated from January 20, 1973 to March 29, 1973 during which a total of twenty distinct tests were performed utilizing linen wastewater. On three days, two sets of samples were obtained for two tests performed when a separate and distinct break occurred in the run, such as the equalization pit running dry. The equalization pit was used for all tests, and again the chemical dosage, surface overflow rate and other parameters were changed to study the effect of independent variable changes on effluent quality. Linens were trucked in from various laundries to provide enough soil for the treatment system. Composite samples of vacuum filtrate, scum, flotation effluent, raw wastewater, and DE effluent were obtained for all tests during the entire length of the operation. Only one set of heavy metal determinations was made, as it was felt that this was not a significant problem for linen wastewater. A wastewater reuse test was performed on April 19, 1973 in a manner similar to the other two wastewater reuse tests conducted.

Operating data for the above mentioned tests are presented in Table C-10 of Appendix C. Tables C-11 and C-12 of this same appendix present the vacuum filter operating data and effluent quality analyses for this same test work, respectively. No significant relationships between the variables of flotation effluent suspended solids, grease, surface overflow rate, calcium chloride dosage, mass loading, or suspended solids and grease removal efficiencies were found to exist. Upon examination of the flotation effluent quality data for all tests, it is evident that no such relationships are necessary, as only one flotation effluent suspended solid concentration is greater than 200 mg/l and only

TABLE 72

THE EFFECT OF VARYING THE TIME INTERVAL BETWEEN CALCIUM ADDITION AND POLYELECTROLYTE ADDITION ON THE FORMATION OF AFTERFLOC ON LINEN LAUNDRY WASTEWATER

Time Interval	Turbidity, FTU		Si, mg/l as SiO_2			After Floc
				After 4 days		
	Initial	After 20 hrs	Initial	Total	Supernatant	
1/2 min	120	270	410	418	268	much, formed quickly
1 1/2 min	65	170	375	375	300	some, formed overnight
3 1/2 min	43	70	338	342	285	some, formed overnight
10 min	37	38	300	300	285	none overnight; trace formed later
overnight	--	44	246	234	225	none overnight; trace formed later

Test Procedure: 2500 mg/l $CaCl_2 \cdot 2H_2O$ added to waste, mixed, then allowed to stand 1/2, 1 1/2, 3 1/2, 10 min and overnight. A23 was then added, the waste mixed 1 minute and allowed to settle. The hanging floc in the supernatant was removed by filtration through 541 paper. Filtrate was allowed to stand to observe afterfloc formation.

Results:

1. The amount of afterfloc formed is indicated by the increase in turbidity after storing overnight.

2. The silica content of the samples did not change appreciably over a period of 4 days. There was no evidence of scale forming on the container glass walls.

3. After the afterfloc settled, the supernatant contained significantly less silica indicating that the afterfloc may be a calcium silicate material.

three flotation effluent greases exceed 100 mg/l. All tests conducted provided good results regardless of operating conditions. This is an acceptable discharge for all municipal sewer ordinances investigated during this project, as shown in Appendix A. It is obvious that the performance of the flotation unit was adequate under a wide variety of conditions. The higher flotation effluent concentrations of suspended solids and grease could not be attributed to high overflow rates or to low calcium chloride dosages, as other runs at equivalent calcium chloride dosages and overflow rates produced adequate results.

The maximum flow that could be obtained from the linen return pump during this testing was 515 lpm (136 gpm). It is felt that due to the nature of the wastewater, the flotation tank can operate at least at the same flowrate as it could for uniforms and that 75% recycle provides plenty of solids separation. Based on raw wastewater suspended solids analyses, 50% recycle would be adequate utilizing the rule of thumb that 100% recycle is required for every one half percent solids. Therefore, 50% recycle is plenty for linen wastewater of the characteristics of this study. It may be noted from Table C-12 that the vacuum filtrate was always of excellent quality containing generally less than 100 mg/l suspended solids. The vacuum filtrate of March 28, 1973 contained only 38 mg/l grease. Thus, the vacuum filtrate is suitable for discharge to the sewer. It does not have to be recycled back to the rapid mix chamber. This further increases the capacity of the flotation unit by about 40 lpm (10 gpm) since the filtrate flowrate was generally 75 to 100 lpm (20-25 gpm) and the vacuum filter only had to be operated one half of the time of the flotation unit. Therefore, based on an optimum overflow rate of 98 lpm/sq ft (2.4 gpm/sq ft) and 50% recycle and not recycling the vacuum filtrate, the flotation tank at the Roscoe laundry can be rated at 659 lpm (174 gpm) for linen laundry wastewater. The nine minute detentiom time available in the flotation tank was adequate for linen wastewater as evidenced by the effluent quality data. Therefore, a large flotation unit is not required.

Table 74 presents average effluent analyses and removal percentages for BOD, TOC, suspended solids and grease for the 20 tests performed. The 95% confidence limits about the sample means are also presented to demonstrate the range of effluent quality obtain. Thus, it can be expected that the parameter under consideration will fall within the range specified 95% of the time. The flotation effluent grease 95% upper confidence limit is 90 mg/l. For BOD and suspended solids, this same statistic is 271 mg/l and 133 mg/l respectively. It is evident that even the worst quality water obtained from the flotation unit reduced the suspended solids, grease, and BOD to levels acceptable for sewer discharge. The DE filter reduced these values to even lower levels: 202 mg/l BOD, 90 mg/l suspended solids, and 62 mg/l grease. Based on these results, the flotation effluent obtained from the linen wastewater treatment at the Roscoe plant is suitable for sewer discharge and would incur no sewer surcharges for BOD or suspended solids.

TABLE 73

LINEN WASTEWATER TREATMENT
EFFLUENT QUALITY DATA

Parameter	No. of Observations	Mean Value	95% Confidence Limits
Raw Wastewater			
BOD, mg/l	20	501	331-672
TOC, mg/l	20	410	311-510
Total Solids, mg/l	20	4,061	2,418-5,705
Suspended Solids, mg/l	20	852	384-1,320
Grease, mg/l	20	207	163-251
Flotation Effluent:			
BOD, mg/l	20	222	173-271
TOC, mg/l	20	176	145-208
Total Solids, mg/l	20	3,752	3,130-4,374
Suspended Solids, mg/l	20	101	69-133
Grease, mg/l	20	69	48-90
DE Effluent:			
BOD, mg/l	9	155	108-202
TOC, mg/l	9	120	89-150
Total Solids, mg/l	9	3,521	2,636-4,405
Suspended Solids, mg/l	9	59	29-90
Grease, mg/l	9	47	32-62
Flotation Percent Removal:			
BOD, mg/l	20	42.5	29.7-55.2
TOC, mg/l	20	50.7	40.9-60.5
Suspended Solids, mg/l	20	74.1	62.1-86.1
Grease, mg/l	20	62.1	50.7-73.4
System Percent Removal:			
BOD, mg/l	9	55.6	40.3-70.8
TOC, mg/l	9	64.5	52.3-76.7
Suspended Solids, mg/l	9	81.8	86.7-97.1
Grease, mg/l	9	71.7	55.1-88.2

The linen wastewater reported upon in Table 73 is generally an average linen wastewater in terms of total solids, alkalinity, and suspended solids, but it appears to have a lower BOD and grease content than other linen wastewaters reported on in the literature (compare reference 2 and Table 67). This leads to some concern that the unit will not perform adequately if the concentrations of these parameters were higher. The system only removed an average of 56% of the BOD and 72% of the total grease available. Thus those linen laundries with 1000 mg/l BOD and 500 mg/l hexane soluble contents may not get the desired effluent quality. In this test work, raw wastewater BOD's of 750 mg/l were regularly handled with no degradation of effluent quality, and grease concentrations of up to 350 mg/l were removed to acceptable levels. Generally, the efficiency of a treatment unit will increase with higher influent concentrations up to a certain point. It is expected that this would also be true here. In any case, those linen laundries with a relatively weak waste load can do an effective treatment job for sewer discharge with only a flotation unit; whereas laundries with stronger wastewater, such as discussed previously, will require DE filtration of the flotation effluent. Average suspended solids concentrations of 850 mg/l require flotation separation prior to DE filtration to prevent rapid plugging of the filter. It is anticipated that difficulty in meeting local sewer codes with DE filter effluent will only be a problem for linen laundries with very strong wastewaters. At what concentration level this might occur, cannot be determined from the data obtained in this study.

Table 74 presents the proportions of the type of linen soil washed on each test day. The linens were classified as to soil by the laundry personnel. The heavy soil items were generally aprons and kitchen towels. Medium soil items were generally continuous towels and assorted table linen. White sheets and napkins, as well as other miscellaneous items made up the light soil. It can be seen that the wash volume laundered during this test work generally contained more light soil. This is probably one of the main reasons for the low organic content of the wastewater encountered here. The type of wastewater generated by the soil mix outlined in Table 74 can be satisfactorily treated, unless the definition of soil type differs radically throughout the industry.

The other analyses in Table C-12 of Appendix C indicate that 65% of the time, the flotation effluent pH was less than 10 and required no neutralization. On one day, it was 12.7, but this appears to be excessive compared to what is normally obtained. The phenolphthalein

TABLE 74

TYPE OF LINEN SOIL HANDLED BY THE WASTEWATER TREATMENT SYSTEM FOR EACH TEST DAY

Test Day	Light Soil Percentage	Medium Soil Percentage	Heavy Soil Percentage
2/20/73	62	19	19
2/21/73	62	19	19
2/22/73	44	22	34
2/23/73	53	32	15
2/27/73	32	45	23
2/28/73	48	26	26
3/1/73	41	36	23
3/14/73	39	43	18
3/15/73	26	52	22
3/16/63	32	36	32
3/20/73	42	46	12
3/21/73	50	38	12
3/22/73	31	44	25
3/23/73	33	33	34
3/28/73	30	50	20
3/29/73	29	47	34
4/19/73	33	42	25
AVERAGE	40	37	23

alkalinity of the flotation effluent was almost always 100 to 120 mg/l indicating very little acid neutralization of linen laundry wastewater effluent will normally be required. Thus neutralization costs can be expected to be low.

Analysis for heavy metals of the linen laundry wastewater did indicate trace amounts of copper, lead, zinc, and nickel. The only problem area appeared to be lead which was measured at 0.7 mg/l. However, it is felt that most of the heavy metals measured probably came from sources other than the linen wastewater especially noting the character of the industrial laundry washwater. One of the linen washing machines was used to launder wipers during this test period when the treatment system was not being operated. So it is possible that this action could leave heavy metal residuals behind in the wash wheel and the water trench receiving the dump. The equalization pit may also have contributed some heavy metals. At any rate, the treatment system removed all the heavy metals measured to acceptable levels. If the linens did contribute the metallic components of the wastewater, the treatment method employed is capable of removing them.

For linen wastewater treatment, the treatment system performed very consistently over a wide range of operating conditions, as demonstrated by Table 74. When the DE filter was operated, effluent grease never exceeded 87 mg/l, BOD never exceeded 274 mg/l, and suspended solids never exceeded 115 mg/l. This indicates that an effluent always meeting sewer codes is generated by the treatment system. The radical changes in removal efficiencies and effluent quality experienced for the uniform and industrial laundry wastewater treatment were not demonstrated for the linen laundry system. Evidently, because the linen laundry wastewater is weaker and does not contain as many materials, the treatment mechanisms are less complex and do not cause as much unpredictability in waste treatment techniques. The linen wastewater tended to have lower suspended solids, TOC and alkalinity than the uniform wastewater, as well as fewer heavy metals. The linen wastewater contained more BOD, while grease and total solids were about the same. The higher BOD values for linen wastewater is probably a function of heavy metal toxicity, as the uniform wastewater contains large amounts of toxic materials. The cause of the differences in the wastewater treatment results may well lie in one of the above observations.

LINEN LAUNDRY WASTEWATER TREATMENT SYSTEM OPERATIONAL RESULTS

No mechanical difficulties were encountered in treating linen laundry wastewater. All components of the treatment system worked effectively during the test period. The one hour equalization period available was adequate for linen wastewater. The flotation unit concentrated the incoming wastewater suspended solids to 0.25% to 4.12%. This entire range of solids concentrations were found to be suitable for vacuum filtration. Generally, 0.25% suspended solids is too thin for vacuum filtration, but it did not present a problem in this instance. Adequate linen waste clarification was achieved at overflow rates of 95 lpm/sq ft (2.3 gpm/sq ft) and 75% recycle. However, because of reasoning presented previously, the flotation unit is rated at 659 lpm (174 gpm) at a 50% recycle ratio.

Calcium chloride chemical treatment is effective over a wide range of dosages, 800 to 2,500 mg/l. However, 1,250 mg/l generally produced a large stable floc, strengthened by 2 mg/l polyelectrolyte.

Vacuum filter blinding is not a problem for linen sludge dewatering. The cake readily picked up and dewatered to 25% solids with little difficulty. At times, the cake would only dewater to 15% solids, for which the reason is not clear. The majority of the time, however, 20% to 25% cake solids were readily attainable. The cake itself was pure white and was not as greasy as uniform or industrial laundry wastewater sludge. This fact prevents it from liquifying to a great extent from the Moyno pump action. Consequently, it would be possible to handle this sludge as a solid fill material. It was not handled as such during this project, as commitments had already been made to a liquid hauler. This could lead to significant costs savings in linen laundry treatment. However, this sludge is putrescible, whereas the uniform and industrial sludges were not. Consequently the sludge must be hauled away on a regular basis, to prevent serious odor problems. The filter yield obtained was proportional to scum suspended solids, as these two parameters provided a 0.63 correlation coefficient, a correlation significant at the 95% level of confidence. The vacuum filtrate was of excellent quality as previously noted. The 10.22 sq m (110 sq ft) vacuum filter used here only had to be operated 1/4 to 1/2 the time of the treatment system operation to dewater all the sludge. Consequently, a vacuum filter one half the size of this one could be employed for this linen waste.

The DE filter operation was very satisfactory for treating flotation effluent. Differential pressure buildups of 0.1 to 0.3 kg/sq cm/hr (1 to 3 psi/hr) were obtained using no body feed. In fact, the same DE was reused several times and still no great surges in differential pressure increases were obtained nor was a degradation of effluent quality evident. The DE filter would need to be precoated only once, per shift to provide a good wastewater effluent.

The optimum linen laundry wastewater treatment system operating conditions determined from this study are presented in Table 75. All parameters presented in this table are as previously discussed.

Table 76 presents the operating results of the system. The scum volumes were estimated from the vacuum filtrate flow and the proportion of time the vacuum filter operated. A five to ten fold sludge volume reduction takes place in the vacuum filtration dewatering step,

TABLE 75

OPTIMUM OPERATING CONDITIONS
FOR THE LINEN LAUNDRY WASTEWATER TREATMENT SYSTEM

Flotation Overflow Rate	98 lpm/sq m
Flotation Recycle	50%
Flotation Detention Time	9.5 minutes
Equalization Time	1 hour
$CaCl_2$ Dosage	1,250 mg/l
Polyelectrolyte Dosage	2 mg/l
Detention Time Between Two Chemical Additions	1 hour
Vacuum Filter Cycle Time	5.5 minutes
Vacuum Filter Pickup Time	0.8 - 1.2 minutes
Vacuum Filter Vacuum Level	>25 cm Hg.
DE Filter Hydraulic Loading	18 lpm/sq m
DE Precoat	0.74 kg/sq m
DE Body Feed	None

TABLE 76

GENERAL OPERATING RESULTS OF THE LINEN LAUNDRY TREATMENT SYSTEM

Flotation Scum Volume	40 - 60 1/1,000 1 raw flow*
Sludge Volume	4 - 8 1/1,000 1 raw flow
Sludge Moisture	75% - 85%
Filter Yield	7 - 17 kg/sq m/hr
Filter Blinding	0%
Vacuum Filtrate Flow	70 - 95 lpm
DE Pressure Buildup	0.15 - 0.30 kg/sq cm/hr

* Estimated from filtrate flow and vacuum filter time.

producing a relatively dry cake, even at low scum solids concentrations. Sludge volumes were calculated from an assumed 1.077 gm/cc (9.0 lbs/gal.) density. The DE pressure buildup occurring in the majority of the tests were minimal. Thus a DE filter loaded at 18 lpm/sq m (0.45 gpm/sq ft) could be operated for a full shift without backwashing.

LINEN LAUNDRY WASTEWATER TREATMENT SYSTEM OPERATING COSTS

Table 77 presents the linen laundry waste treatment operating costs, as obtained from the demonstration unit. The chemical coagulant cost is based upon adding 1,250 mg/l $CaCl_2$ and 2 mg/l anionic polyelectrolyte. Neutralization costs are based on neutralizing 100 mg/l effluent alkalinity as calcium carbonate with sulfuric acid. Power costs and material and maintenance costs are the same as discussed in the previous two sections. Diatomaceous earth costs are figured on the addition of 72 mg DE per liter (0.6 lbs/1000 gal.) of wastewater. No body feed is provided. Sludge disposal costs are based on hauling 6 liters of sludge per 1,000 liters of wastewater treated at 1.2¢/liter (4.5¢/gal.). The cost is one third of this if the cake is hauled away as a solid.

Capital costs are based on the same conditions as previously discussed with the system rated at 659 lpm (174 gpm). For two shift operation, the amortized costs are 4.0¢/cu m (15¢/1000 gal.) and 2.6¢/cu m (10¢/1000 gal.) for a three shift operation. The total operating cost is then 40.1¢/cu m ($1.52/1000 gal.) at the Roscoe plant compared to twice this amount for industrial laundry wastewater. The costs could be reduced to 32¢/cu m ($1.21/1000 gal.) if the cake is hauled as a solid and coagulants are bought in bulk.

Linen laundry wastewater costs much less to treat than uniform or industrial laundry wastewater. The costs are still considerable, however. At 32¢/cu m ($1.21/1000 gal.), this would raise the cost of linen laundering by 0.9¢/kg (0.4¢/lb). It may be noted that any surcharges for BOD and suspended solids will be done away with by wastewater treatment, but this is not a large savings as indicated by the industrial waste survey (Appendix A). Approximately 2.6¢/cu m (10¢/1000 gal.) may be recovered by eliminating this charge. It would not be economical to treat this wastewater strictly on the basis of surcharge reduction. However, linen laundries will find themselves put in a position forced to treat wastewater in many cases due to alkalinity and hexane soluble limitations of municipal sewer ordinances.

Waste treatment costs will vary considerably dependent on the type of soil, laundry location and size, sludge handling methods, etc. Therefore, these costs cannot be taken as absolute, but are only directly applicable to the demonstration treatment system. It should be possible to obtain some idea of wastewater treatment costs by extrapolating the data presented here if the particular wastewater characteristics are known.

TABLE 77

OPERATING COSTS FOR LINEN LAUNDRY WASTEWATER TREATMENT IN ¢/CUBIC METER

Coagulation Chemicals	14.0 (10.6)[a]
Sludge Disposal	7.1 (2.4)[b]
Neutralization	0.8
Power	2.6
Material and Maintenance	6.6
Amortization - 20 yrs @ 6%	7.7
Diatomaceous Earth	1.3
Total Cost for Sewer Disposal	40.1 (32.0)[ab]

[a] If chemicals bought in bulk.

[b] If hauled as a solid waste at \$3.92/cu m (\$3.00/cu yd.)

LINEN LAUNDRY WASTEWATER REUSE TESTING

The April 19 DE effluent was used in a wastewater reuse test to wash a 182 kg (400 lb) load of red table linens. The effluent from the waste treatment system was pink, which does not harm the red items. Dye is a definite problem generally, as solids separation techniques will not remove it. Any laundry using a lot of dye will find limited application for reusing wastewater for white items. This reuse test was performed in a manner similar to those discussed previously. Samples were obtained from each dump of two loads of table linen, one washed with effluent and one with softened city water. Each dump was analyzed for pH, TOC and total solids with the results reported in Table 78.

In almost all analyses, the reused water contains more alkalinity, TOC, and solid material than the city water, as expected. The final rinse of the table linen is almost the exact same quality as the DE effluent indicating that the majority of the contaminants have been flushed from the linens. Thus, no solids appear to be depositing themselves in the laundered articles.

Based on the differences in the total solids analyses, the reused water dumped 2.25 kg (4.96 lbs) more total solids than the city water laundered articles. All the total solids of the wash load discharge into 6,100 liters (1600 gal.) of wash water. The composited reused wastewater would then be expected to have 5,060 mg/l total solids and the regular wash water 1,360 mg/l total solids. Thus the difference in solids concentration of the two waters is the same as at the start of the test. The city water normally contains 180 mg/l total solids while the system effluent had 3,550 mg/l total solids, a difference of 3,370 mg/l. At the completion of the test, the difference was 3,700 mg/l, indicating that the same amount of soil was washed out of each load.

The first time the water is used, almost 3,300 mg/l solids are added to it. By reusing it, an additional 1,500 mg/l were added. Wastewater treatment would be expected to remove 10% of these solids (based on the averages of Table 73), thus providing 4,500 mg/l in the treatment effluent for the next load of washing to be done. The final solids content after this second load would be expected to be greater than 4,500 mg/l. This trend would be more pronounced for heavier soil items. Once again, it is apparent that dissolved solids buildup will limit the reuse of the wastewater in the laundry.

Personnel at the laundry examined both loads of table linen, and could find no difference in the cleaned quality of the two articles. No grease absorption was visible.

TABLE 78

LINEN LAUNDRY WASTEWATER
REUSE TESTING FOR TABLE LINEN

Operation	Gallons Water	pH - units		TOC - mg/1		Total Solids - mg/1	
		Reuse	City	Reuse	City	Resue	City
Break	216	12.3	12.3	800	1120	17,100	9390
Carryover	655	12.05	12.0	740	570	11,300	4570
High Suds	655	11.4	11.55	590	205	6240	1810
Rinse 1	655	11.0	11.05	400	124	4600	1010
Rinse 2	655	10.75	10.05	285	108	4240	595
Rinse 3	655	10.55	10.2	205	92	3920	537
Rinse 4	655	10.3	9.8	170	84	3690	318
Rinse 5	655	10.05	9.5	160	71	3700	395
Rinse 6	655	9.95	9.1	140	52	3670	317

TABLE 78

LINEN LAUNDRY WASTEWATER
REUSE TESTING FOR TABLE LINEN

Operation	Gallons Water	pH - units		TOC - mg/1		Total Solids - mg/1	
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Break	216	12.3	12.3	800	1120	17,100	9390
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Rinse 4	655	10.3	9.8	170	84	3690	318
Rinse 5	655	10.05	9.5	160	71	3700	395
Rinse 6	655	9.95	9.1	140	52	3670	317

LINEN LAUNDRY WASTEWATER TREATMENT SYSTEM PROCESS EVALUATION AND APPLICABILITY

Based on the results of this test work, it was demonstrated that linen laundry wastewater can be effectively treated to meet all applicable sewer discharge standards, and reduce BOD and suspended solids to levels such that no wastewater surcharges would have to be paid. The application of the treatment system will be mainly in those areas where government authorities are exerting pressure because of hexane soluble violations. This is a problem for all linen laundries. There is no economic benefit to installing a treatment system to reduce sewer surcharges because of the high cost of linen laundry treatment. Therefore, unless a linen laundry is forced to treat wastewater by municipal authorities, there is no point in installing a treatment system.

For light soil linen laundries, only a flotation vacuum filtration system will be necessary to meet sewer codes, while for heavier soil laundries, the DE filter is necessary to increase the overall treatment efficiency. No post treatment after DE filtration would be required. In most instances, linen plants may be designed from bench scale laboratory tests rather than expensive pilot plant testing due to the relative weakness of the wastewater, and lower degree of treatment skill required.

A linen laundry owner washing 10,000 kgs (22,000 lbs) per day may find he will have to invest at least $30,000 for a flotation vacuum filtration system and plan on spending a minimum of $50 per shift operating costs. Capital costs for the linen system are lower due to the smaller size flotation tank and vacuum filter required to handle the wastewater solids. The costs at the Roscoe plant may be considered the other extreme in this case. The exact economics of each laundry will vary from plant to plant.

More information on linen laundry wastewater quality variation is needed to determine the universality with which the above treatment system can be applied. With respect to the fact that most investigators in the past have recommended alum for laundry wastewater treatment, information is required on the variability expected in required chemical treatment techniques due to the changes this makes in sludge handling alternatives. Likewise, the effect of alternate supply systems on wastewater treatment needs to be more fully identified in relation to the overall wastewater treatment picture. The above information plus some knowledge of laundry profits and losses would help provide break even analyses for a variety of wastewater treatment situations.

SECTION VIII

RECOMMENDED WASTEWATER TREATMENT PRACTICE FOR THE LAUNDRY INDUSTRY

Based on the foregoing sections of this report, it is possible to generalize somewhat as to how the laundry industry as a whole should view and handle wastewater treatment. Pertinent observations concerning wastewater reuse can also be made.

As demonstrated by local sewer ordinances, the attitude of the federal government, and the character of laundry wastewater, it becomes evident that the decision for wastewater treatment will soon not be one of free choice. When taking action in this regard, it is imperative that the proper procedure in handling the water pollution problem be employed to prevent needless expenditure of funds and to insure that the desired result is attained.

When embarking upon a wastewater treatment venture, the laundry owner must first identify exactly what the problem constituents are, and if possible where they are coming from. This can be done readily by many analytical laboratories. He must also be aware of the attitude of the enforcement officials so that future problem areas not immediately a concern can be readily ascertained. If the source of a problem can be found, e.g. lead in printer's towels, the problem can be dealt with by eliminating this customer, but it merely shifts the burden elsewhere and does not resolve the ultimate lead problem. More often than not, this will not be possible due to the large number of clients a commercial laundry may have and to the heavy analytical expense required to identify the compounds present in each client's wash. It then becomes a matter of identifying the level and degree of variability of the contaminants under consideration. As noted before, hexane solubles are likely to be prohibited and pH limits specified within certain ranges. In identifying the levels and variation of the contaminant, the laundry owner will want to insure that waste samples representative of what a treatment system would be expected to handle are obtained. Generally, several one hour to two hour composites to represent an equalization basin effluent over a day's operation will be adequate. If the laundry wash mix varies radically, this procedure will want to be repeated several days. Each sample should then be analyzed for the problem constituents.

At this point, a wastewater treatment consultant should be employed to analyze the data generated and obtain additional samples so that a wastewater treatment technique may be identified that will resolve the problem. Based on the consistency and effluent quality of the bench tests, recommendations on whether pilot plant studies are required can be made. As noted previously, for those plants with a heavy metal problem or a complex wastewater similar to the Roscoe laundry requiring a sophisticated treatment technique, pilot plant studies will be required. Though these may cost several thousands of dollars, it is well worth it to protect a $50,000 investment. Smaller laundries, of course may not be able to afford pilot plant work.

Based on the bench test or pilot plant results, a full scale unit can be designed to resolve the water pollution problems. The laundry owner is now in a position to determine exactly his economic position, i.e. how much he may have to increase prices or if he can afford the system at all. Presuming that the owner can afford the treatment system, he should then make provision to do as many of the following items as possible:

1. Find a location for the treatment system away from work areas of high activity to facilitate operation and maintenance of the unit. The treatment system size should not be cut to save space.
2. Provide space for an equalization tank capable of holding at least one hour of his plant flow and space for 20,000 liter (5,000 gal.) bulk chemical tanks.
3. Change supply system to be compatible with the treatment technique employed, if required.
4. Provide an area for locating a sludge hauling container, totally enclosed and inaccessible to children.
5. Assign a good maintenance engineer to the operation of the unit so that he may immediately familiarize himself with the treatment system and plan on allocating one half of his time to the operation and maintenance of the unit. These people will also generally have some practical suggestions on component selection and location that will later provide lower maintenance costs. If possible, he could be sent to a short seminar on waste treatment. These are often given at local universities or in large cities.

The laundry owner is now ready to install the treatment system and begin its operation. If all the preceding steps have been followed and with the aid of a reputable wastewater consultant, the water pollution control problem should now be resolved. Likewise, the laundry owner will no longer have to pay a BOD or suspended solids surcharge.

During the course of the treatment system design, close attention should be given to the area of sludge handling, as it was pointed out that utilizing such chemicals as alum for coagulation will result in a residual scum that is virtually nondewaterable except by expensive precoat filtration. Thus consideration may be given to changing laundry wash formulas to lower the sludge disposal cost, which as shown previously is considerable. The difference between the two sludge disposal technique (alum sludge vs. calcium chloride sludge) will determine if it is economical to change the wash formula. Any future change in the wash formula of course should be anticipated so that its effect on the treatment system can be determined.

WASTEWATER REUSE COST ANALYSIS

In the following analysis, three cases for laundry wastewater reuse will be considered; those laundries with a present washroom cost of 13.2¢/cu m (50¢/1000 gal.), those with a cost of 26.4¢/cu m ($1.00/1000 gal.) and 52.8¢/cu m ($2.00/1000 gal.). We will assume that the water is heated in water storage tanks by steam coils receiving steam from boilers. It is presumed that the coil-water interface is the limiting step in reusing the water in hot applications, as data from this study showed the reused water had no adverse effect upon the articles laundered. Table 79 presents suggested contaminant concentrations suitable for heat exchanger duty (13). The hardness of the wastewater effluent must be reduced considerably. It is also evident that silica and total solids may cause a problem, as these are above acceptable levels. Scaling can be a definite problem, as was demonstrated in the operation of the treatment system, when injecting calcium chloride into a pipeline. Thus, the heat transfer area could be easily fouled.

Due to the quality of the effluent, it must be softened before heating. Likewise it is wise to consider only reusing it for break and suds operations and initial rinses to insure that the integrity of the laundered item is maintained. If the wastewater contains dye, it cannot be reused for white items at all unless another treatment step is added, such as activated carbon adsorption. The degree to which the water may be reused and the quality required for washing will depend on the item laundered, the item's color, and other considerations. This too can be expected to vary from laundry to laundry. Let us presume that the water is only reused in the suds, first few rinse operations, and cold water rinses such that 50% of the wastewater is reclaimed. The percentage could possibly be higher in some laundries. The other portion is discharged to the sewer. This water and the evaporative losses must be made up by the normal water supply, and handled by a softening and heating system separate from the reuse water system.

Figure 22 provides a schematic diagram of where all the flows for such a system go. Based on reusing 50% of the water consumed and 10% evaporative and sludge losses, 50% fresh water makeup is required and 40% of the water

TABLE 79

REQUIRED WATER QUALITY FOR HEAT EXCHANGERS

Parameter	Maximum Level Allowable	Wastewater Effluent
Turbidity, mg/l	50	20 - 60
Total Hardness as $CACO_3$, mg/l	50	1,000
Silica as SiO_2, mg/l	50	20 - 200
Total Solids, mg/l	--	3500-4000

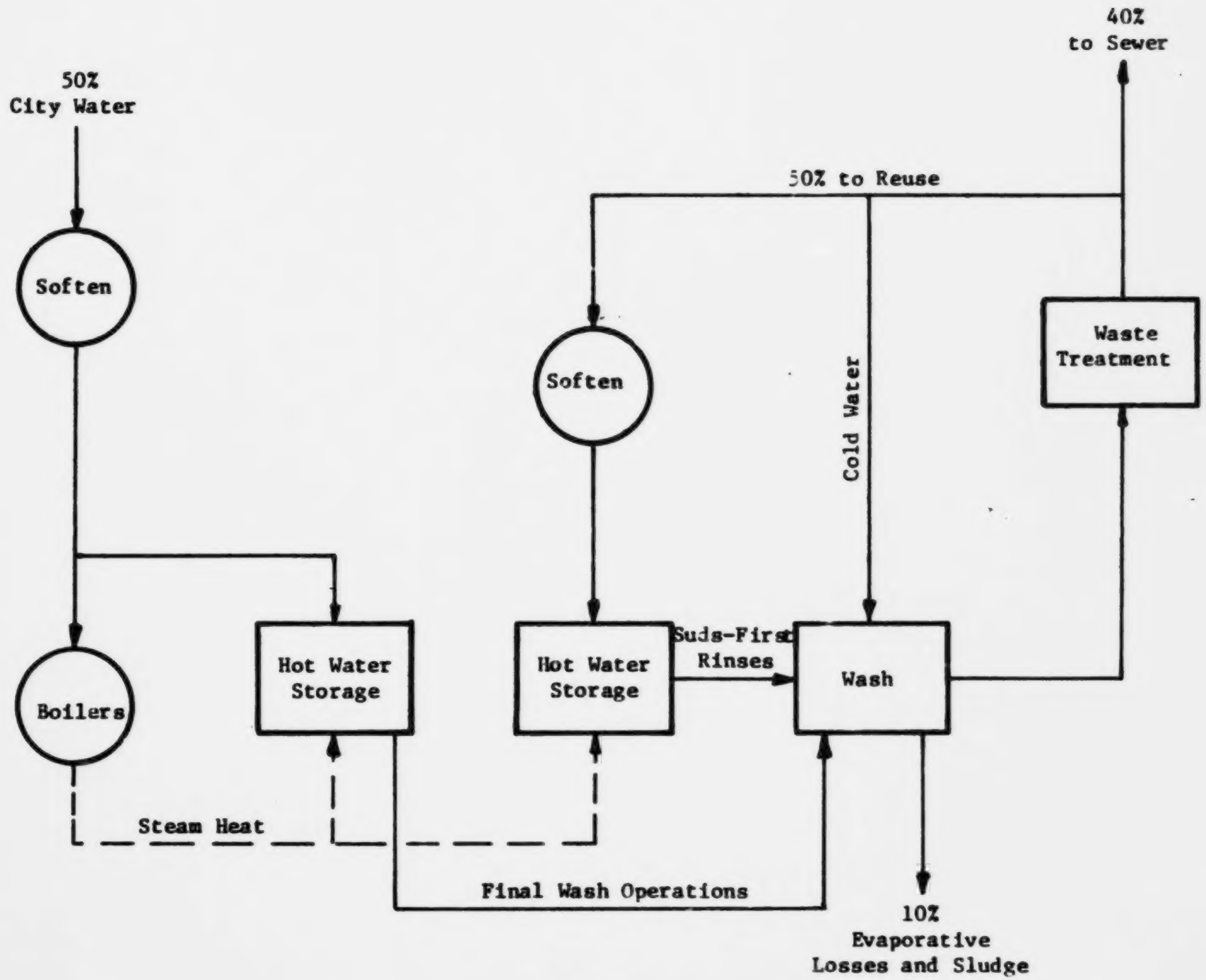
50%
City Water
Soften
Boilers
Steam Heat
Hot Water Storage
Soften
Hot Water Storage
Suds-First Rinses
Final Wash Operations
50% to Reuse
Cold Water
Wash
Waste Treatment
40% to Sewer
10%
Evaporative Losses and Sludge

FIGURE 22
LAUNDRY WASTEWATER REUSE PROPORTIONS

consumed is discharged to the sewer. The average softening costs for both softening streams combined is about 2.4¢/cu m (9¢/1000 gal.) including amortization, if the reuse stream is considered to contain 200 mg/l alkalinity and 1000 mg/l calcium hardness as calcium carbonate (17).

Table 80 summarizes wastewater reuse costs for the three cases cited at the beginning of this section. All costs are given as cents per unit volume of water actually going into the washing machines. Thus the waste treatment costs are 31.7¢/cu m ($1.20/1000 gal.) of wastewater treated; but only 28.5¢/cu m ($1.08/1000 gal.) of water going to the washers, as 10% of the flow is not actually treated. The sludge is included in this 10% to make the calculations easier, and does not actually induce much error. The sewer discharge costs are reported for 40% of the total flow, fresh water costs for 50% of the total flow and softening costs for 100% of the total flow. The total water costs without reuse include waste treatment costs for 90% of the flow, fresh water costs for 100% of the flow, and sewer discharge costs for 90% of the flow. It has been assumed for these analyses that the fresh water and sewer discharge costs are equal in terms of cost per unit volume of water.

Table 80 demonstrates that approximately a 10% savings is realized for 50% water reuse for a laundry with present water costs of 13.2¢/cu m (50¢/1000 gal.). It may be evident that in this instance it does not pay extensively to go to the trouble of bothering with the extra problem of a wastewater reuse system, especially as the cost and maintenance of an extra water heating and storage system must be considered.

For a laundry whose water costs are 26.4¢/cu m ($1.00/1000 gal.) the net savings from reusing 50% of the treated water is 20% of the costs associated with no reuse. For this instance, wastewater reuse is becoming attractive. For a laundry whose water costs are 52.8¢/cu m ($2.00/1000 gal.) a 30% savings in water costs is realized.

Figure 8 of Appendix A indicates that these extreme costs (32¢/cu m) ($1.20/1000 gal.) occur in only 8% of the laundries. Therefore, it is not anticipated that cost savings greater than 20% could be realized on a wide scale. Wastewater reuse will have its most extensive application where raw water costs are high. However, the economics and situation of each individual laundry will be different, and this will affect the wastewater reuse decision.

For the Roscoe laundry which pays only about 8¢/cu m (30¢/1000 gal.) for raw wastewater and no sewer use tax, reuse can offer little cost savings, especially in view of the expensive waste treatment cost. Thus, wastewater reuse application, though technically feasible, will not offer much respite from high operating costs in low water cost areas such as this.

The foregoing discussion can be taken to apply to all types of laundries.

TABLE 80

LAUNDRY WASTEWATER REUSE COST ANALYSES

Item	Water Costs - ¢/cu m going to the Washers		
	13.2¢/cu m (6.6¢/cu m for sewer 6.6¢/cu m for fresh water)	26.4¢/cu m (13.2¢/cu m for sewer, 13.2¢/cu m for fresh water)	52.8¢/cu m (26.4¢/cu m for sewer, 26.4¢/cu m for fresh water)
Discharge Reused Stream to Sewer (40% of total flow)	2.6	5.3	10.6
Raw Water Makeup (50% of total flow)	3.3	6.6	13.2
Softening (total flow)	2.4	2.4	2.4
Wastewater Treatment Costs (90% of total flow)	28.5	28.5	28.5
Total Reuse Water Costs	36.8	42.8	54.7
Total Water Costs without reuse	41.0	53.6	78.7
Net Savings	4.2	10.8	24.0

SECTION IX

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SECTION X

GLOSSARY

1. Afterfloc - Solids formed by the precipitation or crystallization of dissolved material in water upon standing. This material is measured as suspended solids in subsequent analyses.

2. Bench Scale Testing - Laboratory testing that closely simulates full scale waste treatment unit processes and are utilized to size full scale equipment. The tests are quick, portable, and easily performed, e.g. flotation, and vacuum filtration.

3. Break - The first step in a wash cycle in which supplies are used. It is designed to wet down the load and remove as much of the readily soluble soil as possible.

4. Compressibility - Measured by the slope of a specific resistance - pressure logarithmic plot, and indicative of the "collapsibility" of the vacuum filter cake. A compressible sludge does not have a strong pore structure, and collapses under high vacuums.

5. Cycle Time - The time required for a vacuum filter to make one complete drum revolution.

6. DE Body Feed - The addition of filter aid (DE) while filtering wastewater on a precoated DE filter to the wastewater feed; thus providing a continuous clean surface for subsequent solids separation.

7. DE Filter Backwash - The act of reversing the water flow to the DE filter at a flowrate sufficient to knock off the filter cake. This occurs when the filter cake resistance is too great to accommodate the required flow rate.

8. DE Precoat - The initial layer of DE added to the DE filtering elements prior to starting the dirty wastewater feed. Generally, 0.5 to 0.76 kg/sq m (0.1 to 0.15 lb/sq ft) of filter aid is applied to treat the initial wastewater flow.

9. Dissolved Solids - Those solids passing a 0.45 u membrane filter or a glass fiber mat as defined in reference 6 under suspended solids.

10. Dry Time - That portion of the vacuum filtration cycle occurring between the point of drum rotation out of the sludge to the point of vacuum release.

11. Filter Septums - The filter aid support element, generally long tubular stainless steel supports or cloth bag supports, that retain the filter aid.

12. Filter Leaf - A small filter septum of known area that is free draining and utilized for holding filter cloths during vacuum filter sizing bench tests.

13. Flush - A wash operation occurring at the beginning of the wash cycle in which no supplies are added to merely wash out loose soil and dirt to increase the effectiveness of the supplies when they are added.

14. Grease - See Hexane Solubles.

15. Heavy Metals - Lead, Cadmium, Zinc, Mercury, Iron, Chromium, Nickel, and Copper in this report.

16. Hexane Solubles - Any material, e.g., fats, oils, waxes, and other non-volatiles, extracted from an acidified sample of waste by normal hexane.

17. Industrial Laundry - A laundry washing primarily shop towels, printer's towels, and dust mops, wherein the wastewater contamination is abnormally high compared to other laundry types.

18. Linen Laundry - A laundry washing primarily linen flatwork such as sheets, table linen, continuous towels, kitchen towels, etc., wherein the wastewater contamination is low compared to other laundry types.

19. Mass Loading - The mass of suspended solids applied to a unit area of the flotation tank in a unit of time, measured as kgs/day/sq m or lbs/day/sq ft.

20. Pickup Time - That portion of the vacuum filtration cycle occurring during the time the drum is submerged in the sludge.

21. Pilot Plant Testing - Small scale continuous testing of model waste treatment processes to develop design data for direct scale up to full scale equipment.

22. Recycle Ratio - Pressurized flowrate divided by the raw flow rate x 100, expressed as a percentage.

23. Refractory - non-biodegradable.

24. Rise Rate - The rate at which solids separation occurs in a flotation unit, i.e., the velocity with which a suspended particle is lifted in the liquid medium.

25. Scum - The liquid fraction containing the solids that is skimmed from the flotation unit and used as vacuum filter feed.

26. Sewer Charge - A sewer use tax, or cost charged by a municipality to a sewer user to pay for this service.

27. Sewer Surcharge - A sewer tax above the sewer charge determined by the strength of the wastewater discharge, generally in terms of wastewater BOD and suspended solids.

28. Soil - The dirt, grease, and other material present in laundry prior to washing. This is the material that must be cleaned from the articles.

29. Sour - An acid compound added to the last wash operation to adjust the pH of the final rinse to near neutrality.

30. Specific Resistance - A measure of the ability of a vacuum filter sludge cake to impede the flow of water through its pore structure; utilized to measure the effect of sludge chemical conditioning.

31. Submergence - A measure of sludge depth in the vacuum filter, usually expressed as the percentage of the drum diameter beneath the filter vat sludge level.

32. Suds - The wash operation wherein the detergent is added to emulsify oil and greases and to suspend the majority of the soil for discharge.

33. Supplies - The chemicals used for removing the soil in the wash cycle; this includes all chemicals added in the wash cycle.

34. Surface Overflow Rate - The hydraulic loading of the flotation unit per unit area of tank per unit time, usually expressed as lpm/sq m(gpm/sq ft) of tank.

35. Uniform Laundry - A laundry primarily washing shirts, pants, coveralls, and uniforms of various colors and types.

36. Vacuum Filter Blinding - The deposition of solids in the weave of a filter cloth such that the cloth cannot pick up any new solids. On a belt filter, cloth blinding leads to no cake discharge from the discharge roll; therefore, no sludge is being dewatered by those areas manifesting blinding.

37. Vacuum Filter Solids Loading - The mass of dry sludge solids picked up per unit area of filter; a measure of cake thickness.

38. Vacuum Filter Yield - The mass of dry sludge solids dewatered on a unit area of filter in a unit of time, normally measured as kgs/sq m filter/hr (lbs/sq ft/hr).

39. Vacuum Filtrate - The water passing through the filter cloth and not retained in the sludge.

40. Wash Cycle - The entire operation required to launder a machine load of an article.

41. Wash Formula - The complete schedule of application of detergents and other supplies in laundering.

42. Wash Operation - One discrete machine discharge during a wash cycle, e.g. a flush, suds or rinse.

43. Washroom - The area where the wash wheels are located.

44. Wash Wheel - The washing machine itself.

45. Water Level - The depth of water in the cylinder of the wash wheel while it is laundering an item. This depth is often used to calculate the volume of water used in the laundering process, and in the calculation of water volume used in one wash operation.

46. Wipers - Shop towels and printer's towels.

SECTION XI

ABBREVIATIONS

BOD - Biochemical Oxygen Demand

BTU - British Thermal Units

cm - centimeter

cfm - cubic feet per minute

cmm - cubic meter per minute

cu ft - cubic feet

cu m - cubic meter

cu yd - cubic yard

DE - diatomaceous earth

ft - foot

gal. - gallons

gpm - gallons per minute

hp - horsepower

hr - hour

in. - inches

kg - kilogram

kg-cal - kilogram-calories

l - liter

lb - pound

lpm - liters per minute

µ - microns

µg - micrograms

µmhos - micro-ohms

mg - milligram

min - minute

mm - millimeter

mpm - meters per minute

psi - pounds per square inch

sq cm - square centimeter

sq ft - square feet

sq m - square meters

TOC - total organic carbon

SECTION XII

APPENDICES

APPENDIX A

LINEN AND INDUSTRIAL LAUNDRY INDUSTRY SURVEY

LINEN AND INDUSTRIAL LAUNDRY INDUSTRY SURVEY

CONCLUSIONS

1. There is a definite relationship between laundry wash loads and water consumption.

2. Industrial laundries use more water and pay a higher sewer surcharge than linen laundries.

3. Laundry location is much more important in determining water costs than laundry size.

4. Based on the sewer ordinances examined, it would appear that most laundries will have problems meeting the pH and grease standards without treatment. Industrial laundries may have heavy metal problems dependent on what they wash.

5. Industrial laundries have higher washroom water costs per product unit than linen laundries.

6. There is a great deal of variation in water costs, sewer costs and surcharges, washroom costs, and volume of water used per unit weight of laundry for all laundries, due to laundry location, differences in items washed, differences in wash formulas and procedures, etc.

7. Washroom costs for laundries are now about 13¢/cu m (50¢/1000 gallons) for surcharges, sewer use taxes, and raw water (1971 dollars).

RECOMMENDATIONS

1. Expand on the present survey to obtain more data on wastewater quality variation between laundries, and to more specifically delineate water usage rates and costs for the various laundry types.

2. Apply the information obtained from a more detailed survey to specific wastewater treatment conditions and laundry situations so that break even analyses on laundry waste treatment costs can be performed. This will help define the magnitude and scope of the water pollution problem more clearly for the laundry industry.

LAUNDRY INDUSTRY SURVEY

As part of the laundry wastewater treatment demonstration system project, a laundry industry survey was conducted for the purpose of obtaining information on what laundries were paying for water as well as information on water pollution control problems in general for the laundry industry. In this regard, questionnaires were prepared and sent to member laundries of the project supporting organizations requesting information on types of articles laundered, supplies, wash weight per week, water cost and usage. Table A-1 is a duplicate of the questionnaire utilized. The forms were filled out by the member laundries and returned to Envirex for correlation and analysis. A copy of a water bill was requested from each laundry so that the majority of the figures obtained could be substantiated. This report summarizes the responses to those forms.

Approximately 160 forms were received of which 116 were utilized. The remaining 44 forms were not utilized either because the forms were incomplete, did not include water consumption data, or for other reasons. Of the forms used for this survey, 96 were from linen or industrial plants and 20 from diaper plants. All information from the diaper plants is reported in Appendix F. For the purpose of this survey, all plants laundering more than 75% industrial garments, wipers, and mops were considered to be industrial plants; and all plants laundering more than 75% linen flatwork and garments were considered to be linen plants. Using these classifications, 45 of the reporting laundries were industrial, 43 were linen, and eight were combinations of both. Included with the above survey forms were 23 different sewer ordinances and 18 laundry wastewater analyses. All data reported is for the year 1971.

The data obtained was averaged and correlated to obtain information on both the average and range of laundry water consumption and costs. The average water costs and usage for all laundries are presented in Table A-2. From this table, it can be seen that water costs and laundry sizes cover a wide range of values. The wide range of values shown for all parameters should serve as a warning against applying the reported average values indiscriminately. This, coupled with the facts that all water consumption data probably includes sanitary sewage, that there is an indeterminate geographic effect upon the data, and that all water volume data will include results of faulty water meters demonstrates that the data presented should be utilized to only indicate trends and general magnitudes rather than exact or specific relations.

Sewer cost data is not as abundant as water cost data as many launderers included water bills that indicated no sewer charge. However, many municipalities bill this separately, i.e., they do not include it on a water bill. Thus, it is not known how many laundries may have reported no sewer charge since it was not on the water bill, and still have paid a sewer charge. Other laundries indicated there was a sewer charge, but enclosed no bill for it. As much data as possible has been included in Table A-2.

TABLE A-1

IIL - LSAA SURVEY FORM FOR

LAUNDRY WASTEWATER TREATMENT PROJECT

1. Our plant operates:

__________ hours per day - Monday through Friday

__________ hours per day - Saturday

__________ hours per day - Sunday

2. Our average WEEKLY wash poundage (__________lbs) can be broken down as follows:

A. Linen Supply Flatwork

__________ lbs light soil (bed linen, bath towels, etc.)

__________ lbs medium soil (table linen, kitchen towels, etc.)

__________ lbs heavy soil (aprons, bar towels, etc.)

__________ lbs colored linens

B. Linen Supply Garments

__________ lbs whites (cotton) __________ lbs colors (cotton

__________ lbs whites (synthetics)__________ lbs colors (synthetics)

C. Dust Control

__________ lbs mops __________ lbs entrance mats

__________ lbs __________ __________ lbs __________

D. Industrial Flat

__________ lbs shop towels __________ lbs printer towles

__________ lbs __________ __________ lbs __________

E. Industrial Garments

__________ lbs whites (cotton) __________ lbs colors (cotton)

__________ lbs whites (synthetics) __________ lbs colors (synthetics)

TABLE A-1, CONTINUED

3. In addition to the common wash supplies such as alkali, soap, bleach, and industrial detergents, do you use:

Sour	Type ________________
Mildew Inhibitor	Type ________________
Flame Retardant	Type ________________
Non-Ionic Detergent	Phosphates
CMC	Softeners
Solvents	Dust Treating Compounds

4. Has an analysis been made of your wastewater effluent:
If yes:____

City Private Agency

Please enclose a copy of their report.

5. Please enclose copies of the following:

A. Recent monthly water bill. Does bill include:

1. Cost of fresh water?	Yes	No
2. Sewer use charges?	Yes	No
3. Sewer surcharges?	Yes	No

If not, please include this information:

What was the total water consumption in gallons for the period covered by the enclosed water bill? ______________ gallons.

B. Local sewer use ordinance. This will be of vital help in determining typical sewage requirements througout the USA.

Thank you. Please use the reverse side for any additional comments you wish to make.

TABLE A-2

AVERAGE WATER COSTS AND USAGE FOR 96 LINEN AND INDUSTRIAL LAUNDRIES

	Range	Average	No. of Values >0
Raw Water Cost (¢/cu m)	3.2-18.5	7.4	91
Sewer Charge (¢/cu m)	0.5-29.6	5.8	64
Sewer Surcharge (¢/cu m)	0.1-15.9	4.4	22
Water Consumption (1000 lpd)	68-1136	378	68
Laundry Size (1000 kg/week)	54-267	50	95
Liters Water Consumed/ kg laundered	21.6-65.0	38.3	67
Total Washroom Costs (¢/cu m)	3.8-37.0	14.8	64
Washroom Water Costs (¢/100 lgs laundered)	18-134	73	44

It can be seen that laundries were paying an average of 14.7¢/cu m (56¢/1000 gal.) for raw water, sewer charges, and sewer surcharges. This is reported as total washroom costs in Table A-2. This does not include the cost of softening. The average laundry water consumption was seen to be 260 cu m/d (100,000 gpd) for laundering 50,000 kg (109,000 lbs) per week. Twenty-three percent of the laundries reporting were paying a sewer surcharge for BOD and suspended solids. None of the laundries indicated they had waste treatment other than screens or grease traps. Washroom water costs averaged 59¢/100 kgs ($.27/100 lbs) of items laundered. Comparing this to the 110¢ to 220¢ cost per 100 kgs (50¢ to 100¢/lb) laundered for waste treatment will increase water related costs significantly for all laundries, as the maximum washroom water cost was only 134¢/100 kgs (61¢/100 lbs) laundered.

A very good relation was found to exist between laundry size and water consumption, as demonstrated in Figures A-1 and A-2. As laundry wash load increases in size, water consumption also increases linearly. This points up the fact that water consumed per pound of article laundered did not decrease for larger laundries, but that the amount of water required to launder a unit weight of material is evidently independent of plant size. However, the volume of water required per pound of article laundered does depend on the type of article laundered.

The two lines drawn in Figures A-1 and A-2 are least squares regression lines with correlation coefficients of 0.91 and 0.97 respectively. Therefore, 90% to 95% of the plant flow occurring in a laundry can be accounted for by the quantity of articles laundered. Thus by knowing the wash load of a laundry, the amount of water consumed can be reliably predicted for these laundries. By then applying a reduction of 15-20% of this number to allow for evaporation, sanitary usage, and sludge, a fairly reliable wastewater design flow can be determined. The variation in daily wash poundage will determine the daily variation of flow. Thus, wash poundage is a useful wastewater design parameter.

An attempt was also made to correlate water costs with laundry water consumption and volume of water used per kilogram of articles laundered with laundry size. However, there were no correlations of this type present. Laundry location evidently dictates water cost much more so than laundry size. However, for a particular municipality, there would be expected to be a good correlation between unit water cost and consumption since most municipalities charge high volume customers a lower unit rate. The unit water cost for a laundry will be higher in those areas where water is scarce.

In general, laundries in the northeast paid the highest water costs and laundries in the midwest and south had the lower water costs. Likewise, there was no correlation between laundry size and volume of water consumed per unit mass of laundered articles. Apparently, large laundries do not use water any more efficiently than small ones, and there is a fixed volume of water required to get a unit weight of article cleaned.

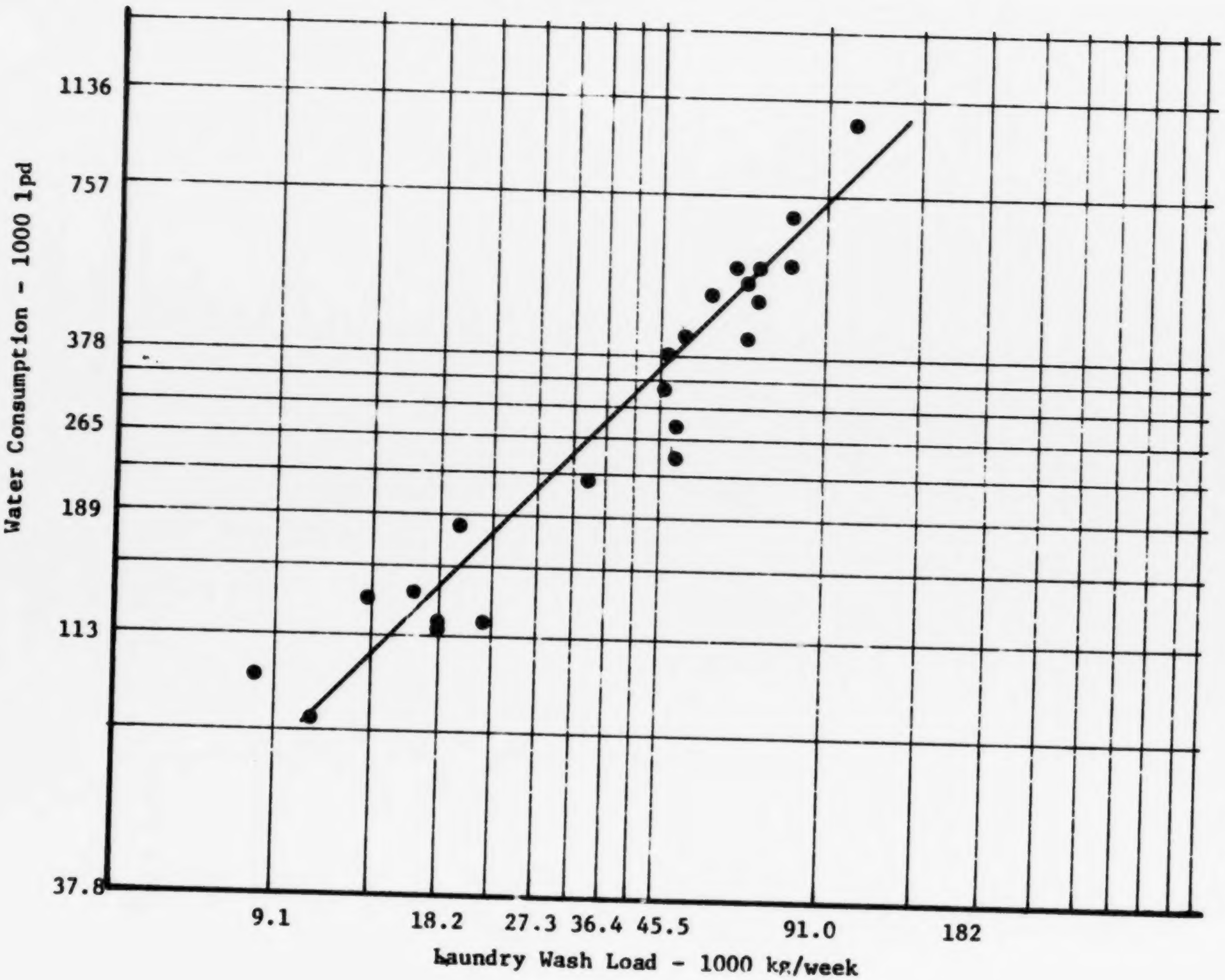


FIGURE A-1
WATER CONSUMPTION VS. INDUSTRIAL LAUNDRY SIZE

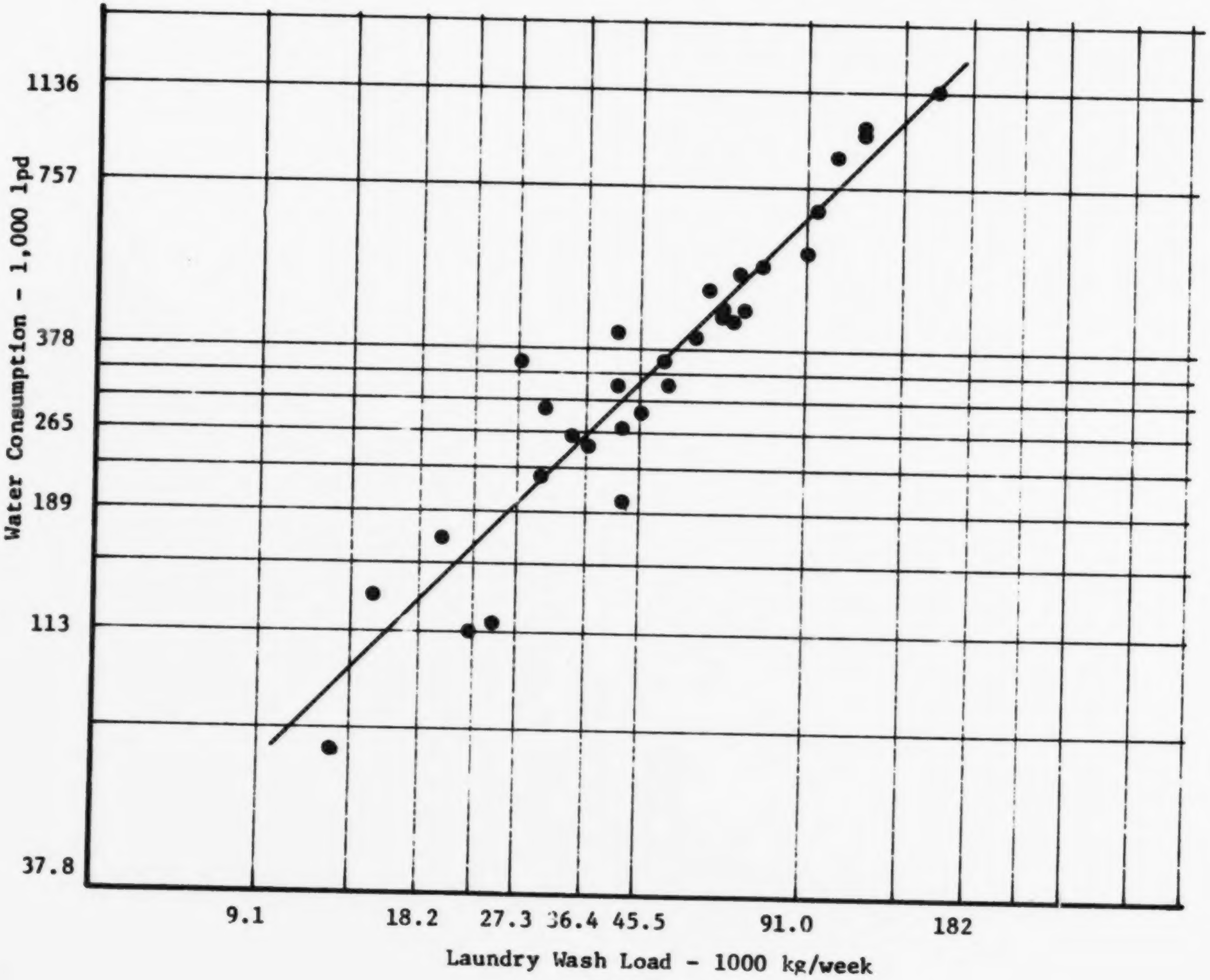


FIGURE A-2

WATER CONSUMPTION VS. LINEN LAUNDRY SIZE

Table A-3 presents a survey comparison of linen and industrial laundries. From Table A-3 it can be noted that for the laundries surveyed, it appears that industrial laundries consume about 10% more water than linen laundries per unit mass of article laundered. This figure seems low in view of the fact that many industrially laundered items will generally have 4-6 more rinses than linen laundered items. However, this data is an indication that industrial laundries in general do use more water per unit weight of laundered items. This cannot be taken as an exact figure due to the limitations of the survey previously cited. Likewise the slopes of the two lines of Figures A-1 and A-2 demonstrate about the same difference; as the slope of the linen laundry curve is 39.1 l/kg laundered (4.7 gal./lb) and the industrial curve 42.5 l/kg (5.1 gal./lb).

It may also be noted from Table A-3 that average sewer and water costs are almost equal for industrial and linen laundries, which is to be expected. Industrial laundries pay a sewer surcharge approximately 2 1/2 times higher than linen laundries due to the higher concentrations of BOD and suspended solids in their wastewater, as shown in Table A-3. This same table indicates that the linen laundries responding to the survey were somewhat larger than the industrial laundries. It is not known if this is generally true or merely characteristic of those laundries responding to the survey. Total washroom water costs are about equal for linen and industrial laundries in cents/cubic meter. However, when expressed in terms of cents per 100 kgs of articles laundered, it can be seen that industrial laundering washroom water costs are about 20% greater than linen laundry washroom costs. This is due to the facts that industrial laundries do use more water and pay higher sewer surcharges. Figures A-3 and A-4 depict this information in a frequency distribution histogram. These figures demonstrate that about 50% of the industrial laundries have washroom costs greater than 66¢/100 kgs (30¢/100 lbs) laundered while only 17% of the linen laundries exceed this figure. Logically, this is a good check on the survey results since this type of information would normally be anticipated.

Figures A-5, A-6 and A-7 depict similar histograms for raw water costs, sewer charges, and sewer surcharges. These histograms are not separated into linen and industrial laundries, as there was no significant difference in the data between the two laundry categories for raw water and sewer charge costs. The surcharge data was not separated, because there were not enough data points to provide a realiable histogram. The variation obtained in this cost data is self-evident, with the most frequently occurring costs being the following:

water cost - 6.6 to 7.9¢/cu m (25¢ to 30¢/1000 gal.)
sewer charge - 2.6¢ to 5.3¢/cu m (10¢ to 20¢/1000 gal.)
surcharge - 0 to 1.3¢/cu m (0 to 5¢/1000 gal.)

Thus, it can be seen that water is relatively cheap for the majority of laundries, and that waste treatment for the sake of reducing surcharges would have to be exceedingly economical. As evidenced in the main report, this was not the case. The wide range of values reported by the laundries

TABLE A-3

COMPARISON OF WATER COSTS AND USAGE
FOR LINEN AND INDUSTRIAL LAUNDRIES

Item	Range		Average		No. of Responses	
	Linen	Industrial	Linen	Industrial	Linen	Industrial
Raw Water Cost (¢/ cu m)	3.2-18.2	3.2-18.5	7.4	7.7	40	43
Sewer Charge (¢/cu m)	1.1-21.9	0.5-29.6	6.1	5.8	28	29
Sewer Surcharge (¢/cu m)	0.1-6.3	0.8-15.9	2.4	6.1	11	10
Water Consumption (1000 lpd)	68-1136	79-1022	443	326	36	37
Laundry Size (1000 kg/wk)	13.2-262	8.6-102	60	44	44	45
Liters Water Consumed/ kilogram laundered	21.7-65.0	24.2-55.8	36.7	40.0	35	26
Washroom Water Costs (¢/cu m)	5.3-28.0	4.0-35.7	14.8	15.3	30	28
Washroom Water Costs (¢/100 kgs laundry)	18-128	24-134	53	65	23	18
Wastewater BOD (mg/l)	305-1300	18-2500	869	1154	8	8
Wastewater Suspended Solids (mg/l)	275-910	1100-3998	556	1988	8	8

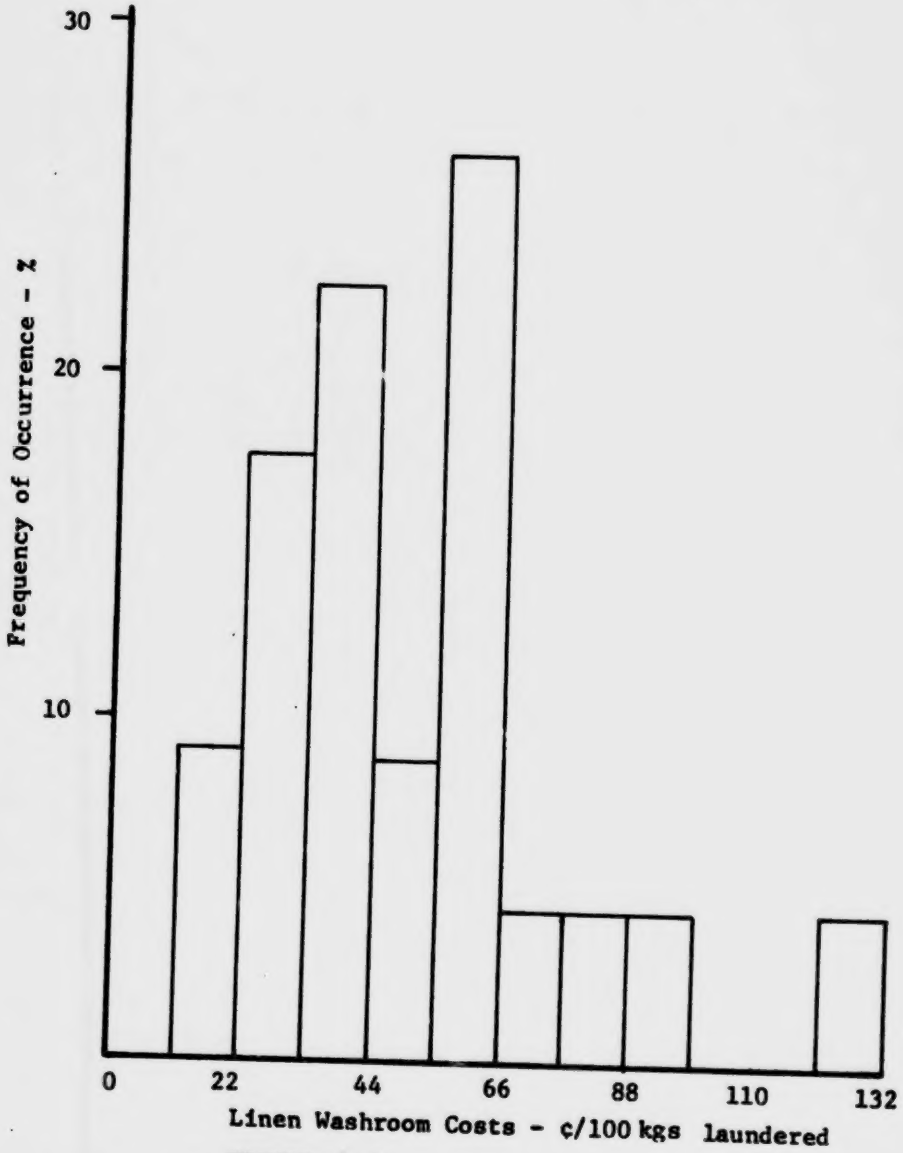


FIGURE A-3
LINEN LAUNDRY WASHROOM COSTS INCLUDING SEWER USE TAXES, FRESH WATER COSTS, AND SEWER SURCHARGES AS A FUNCTION OF PRODUCT UNIT WEIGHT

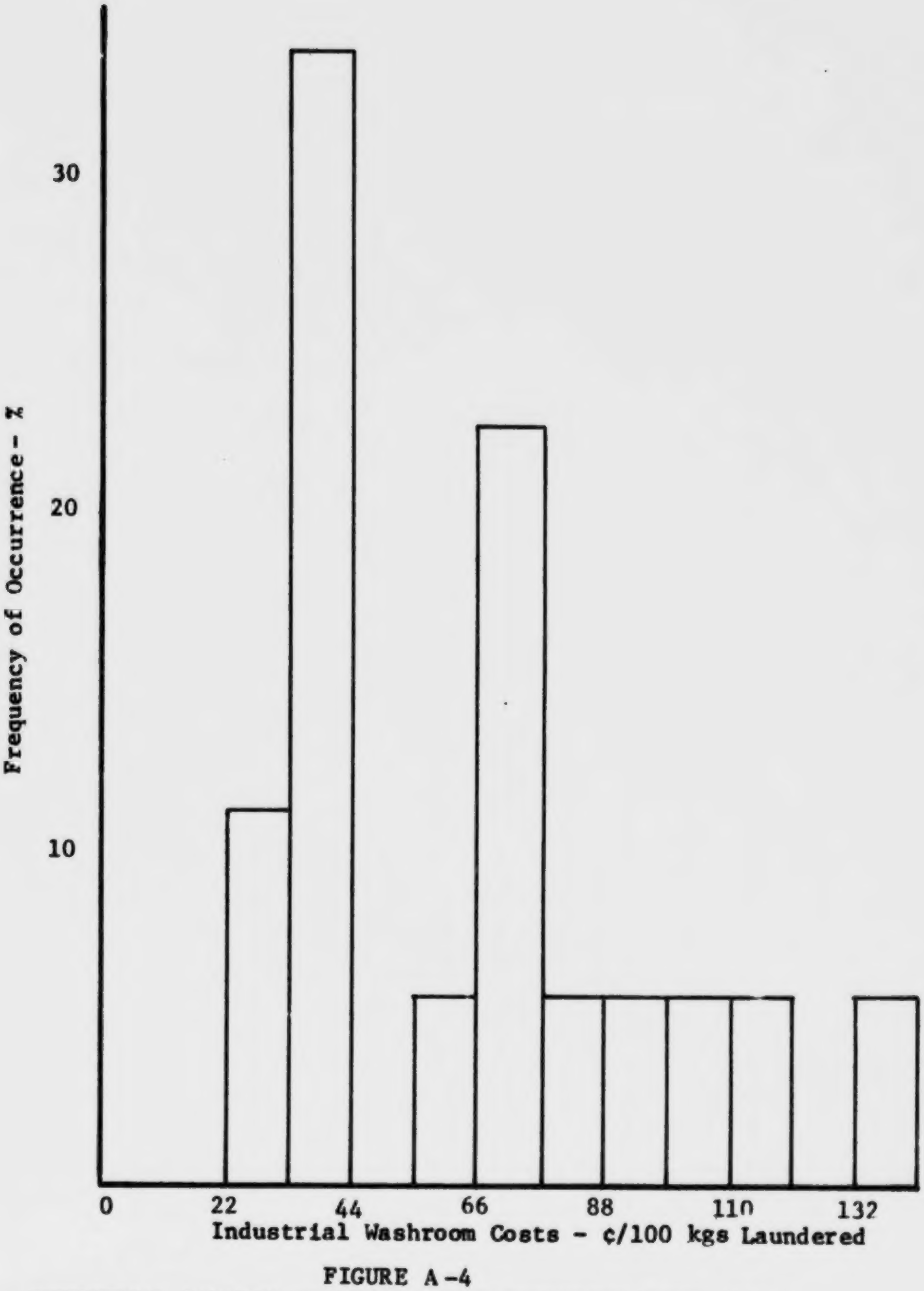


FIGURE A-4
INDUSTRIAL LAUNDRY WASHROOM COSTS INCLUDING SEWER USE TAXES, FRESH WATER COSTS, AND SEWER SURCHARGES AS A FUNCTION OF PRODUCT UNIT WEIGHT

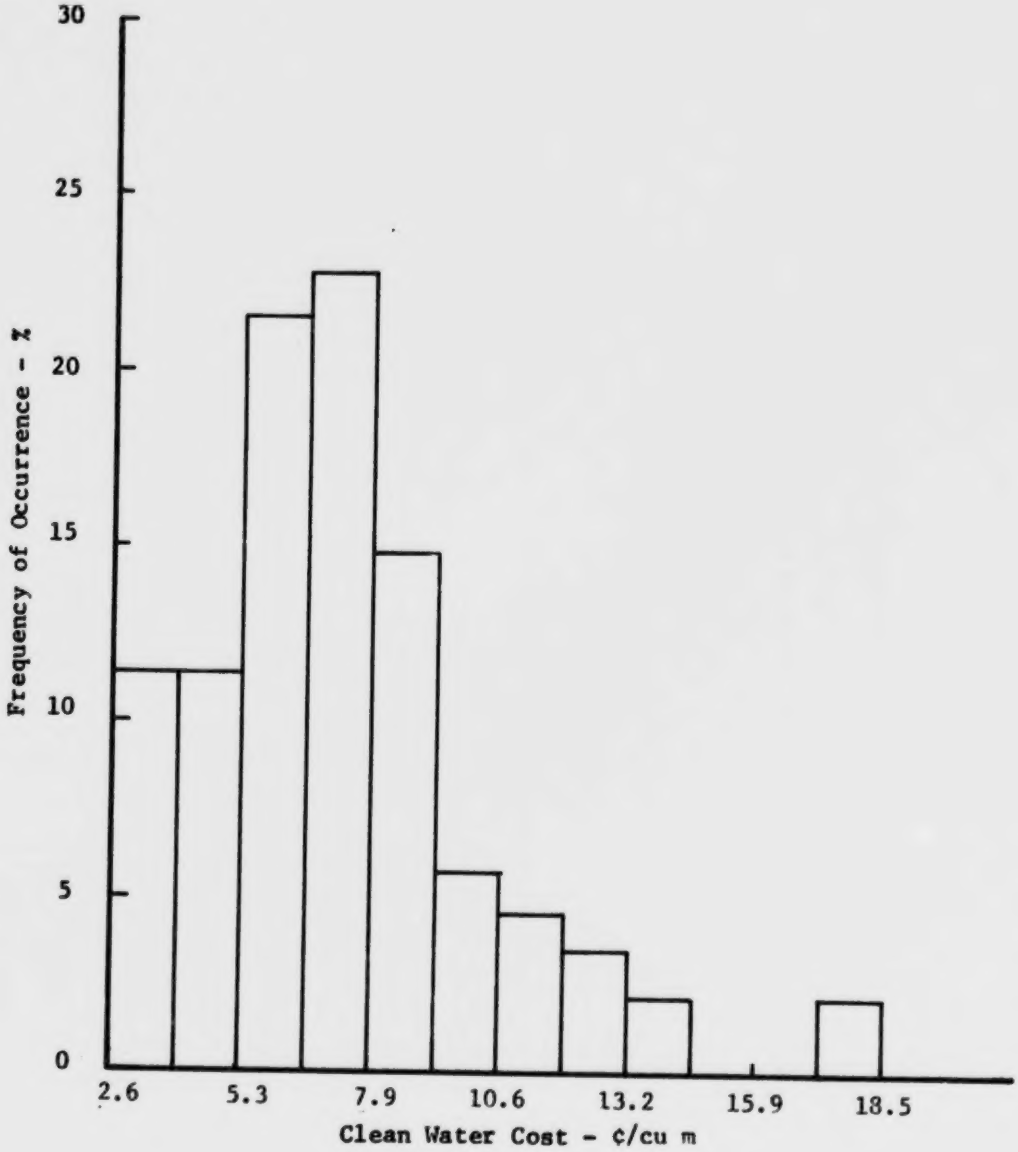


FIGURE A-5

FRESH WATER COSTS FOR LAUNDRIES

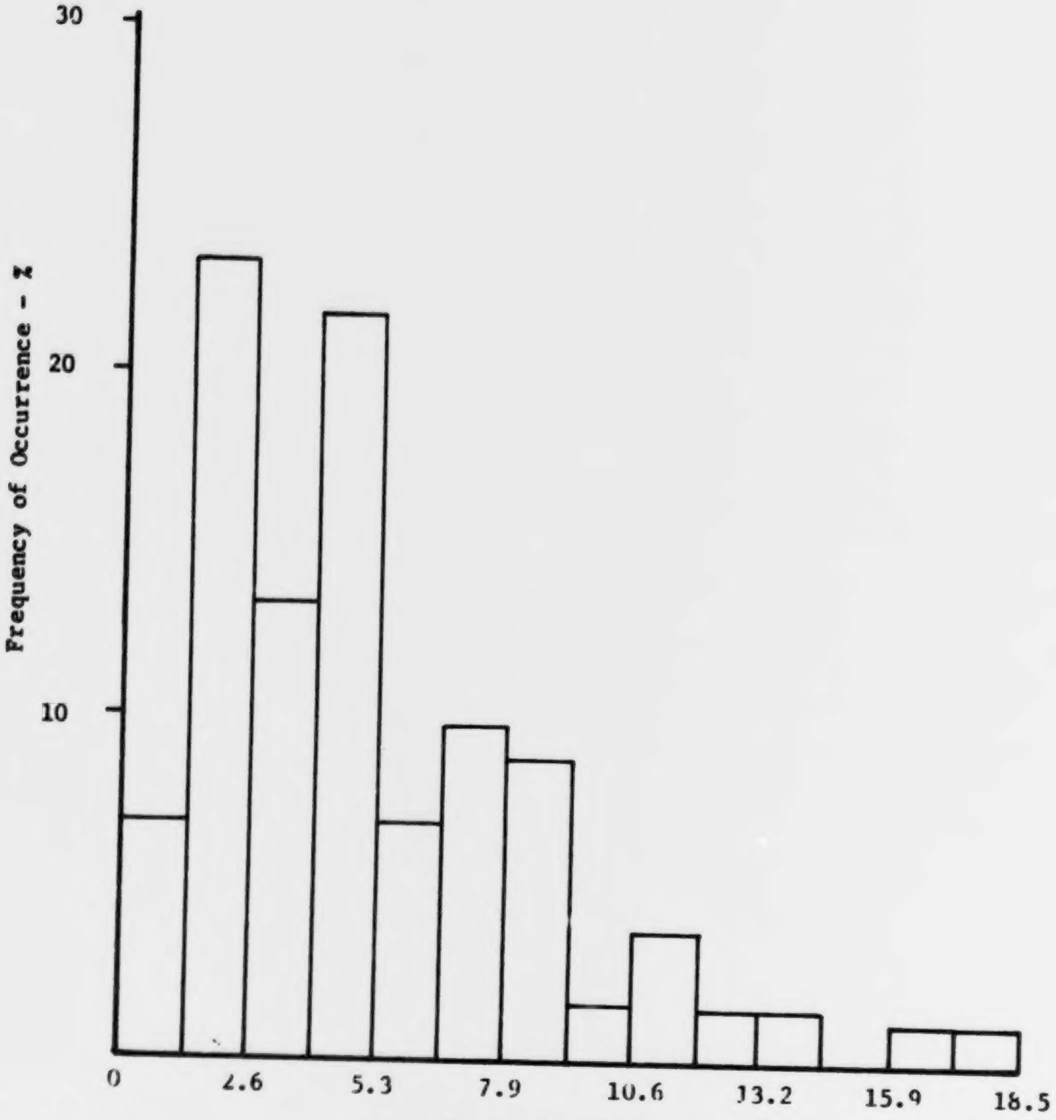


FIGURE A-6
SEWER USE CHARGES FOR 100 LAUNDRIES

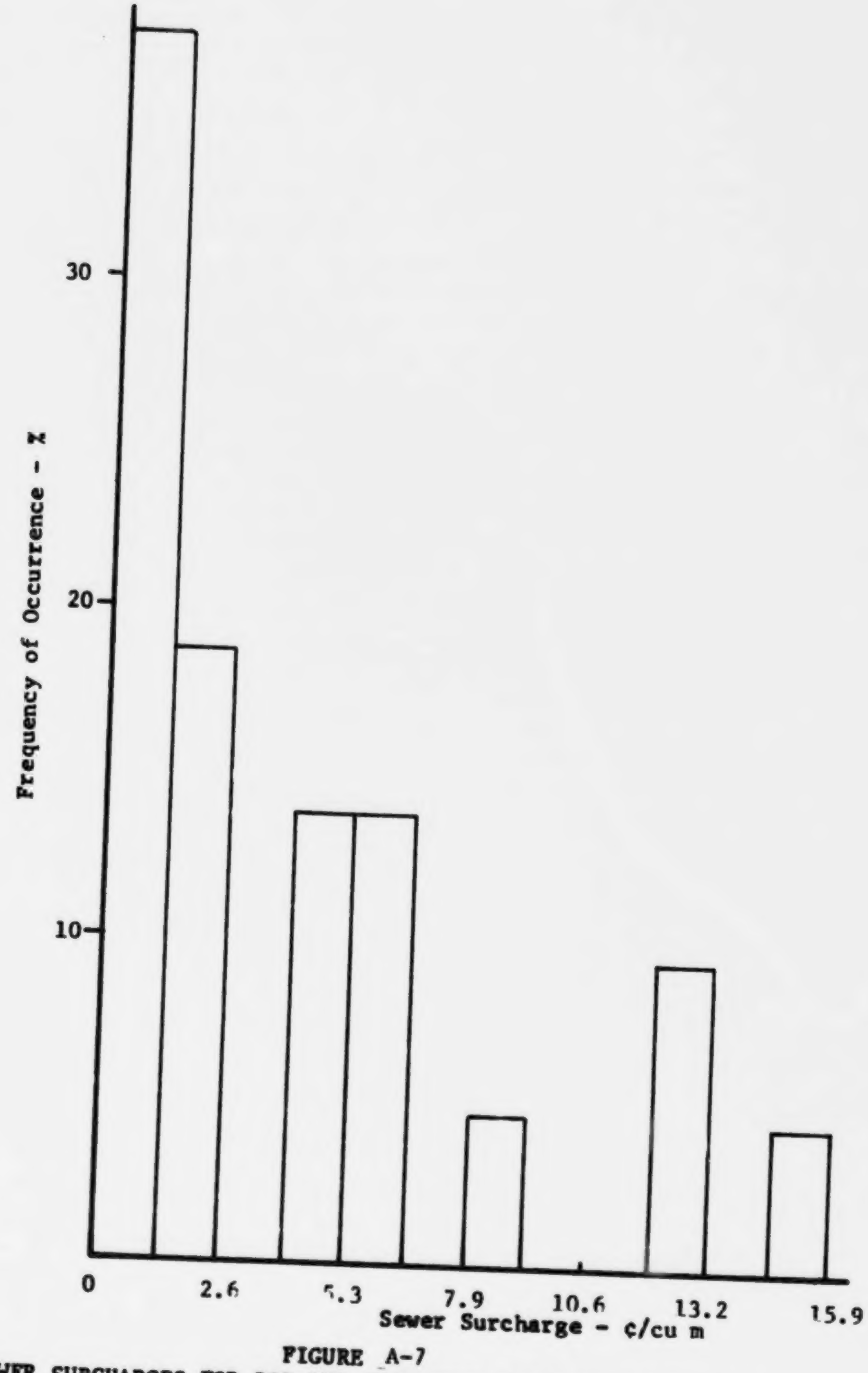


FIGURE A-7
SEWER SURCHARGES FOR BOD AND SUSPENDED SOLIDS FOR LAUNDRIES

also amply demonstrates that each individual laundry will have to consider the economics of wastewater treatment from its own unique position. Figure A-8 presents the total washroom costs in histogram fashion, and demonstrates that the majority of laundries pay 8¢ to 13¢/cu m (30¢ to 50¢/1000 gal.) for water and sewer. Those costs go as low as 2.6¢/cu m (10¢/1000 gal.) and as high as 37.0¢/cu m ($1.40/1000 gal.). Waste treatment is of course more economical for those laundries with high costs when wastewater reuse is considered.

Table A-4 presents the ranges of contaminant concentrations allowed in sewer discharges for 20 different municipal sewer ordinances included in the industrial survey. The table shows a wide range of concentrations allowable for almost all substances. Of particular interest to all laundries are the pH and grease limitations. In general, almost all laundries will exceed these standards; and many industrial laundries will have problems with some of the heavy metals. It may also be noted in regard to sewer ordinances that many of the smaller municipalities will have an ordinance that states merely "no toxic substances or substances that may interfere with the treatment processes shall be discharged to the sewer in concentrations considered by the city engineer to be excessive." Thus, they do not put a number or limitation on anything that is discharged, but leave it to their own discretion. In these instances, the same problems that occur with the ordinances that set specific limits also occur, perhaps more so. Temperature and the other items were not large problems.

It may be noted that standards for such ordinances are not going to become more lax but more stringent. In some instances, municipalities are no longer applying a surcharge to wastewater BOD and suspended solid but are merely requiring any sewer user with BOD or suspended solids above a specified level to treat their wastewater to reduce these parameters to the required concentration. Therefore laundries can expect wastewater treatment to become a very large part of their future. Newly constructed laundries should have the wastewater treatment system designed in with the plant just as the washers, driers, and ironers are; since in the long run, almost all laundries are going to be faced with unfavorable municipal attitudes towards their discharges. Since laundries come in all sizes and types, the variety of treatment methods will be considerable.

All the data obtained from the industrial survey is reported in Table A-5.

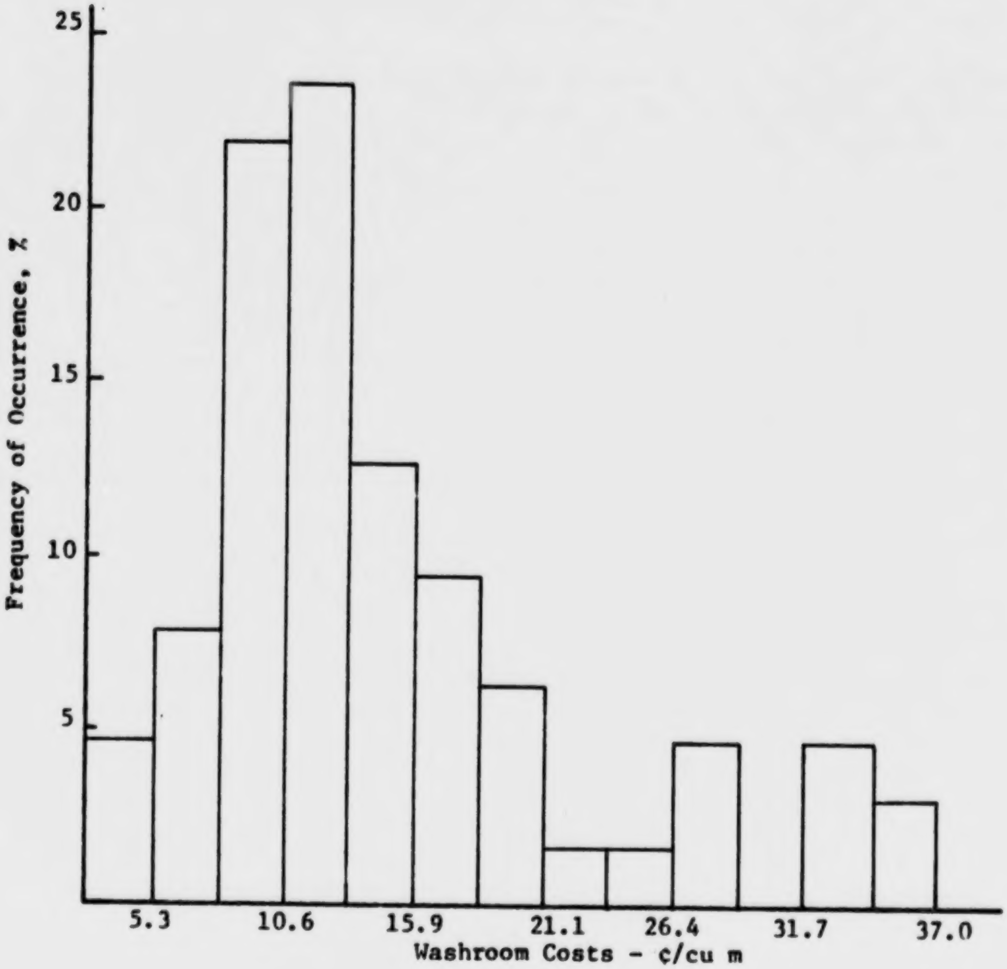


FIGURE A-8
LAUNDRY WASHROOM WATER COSTS INCLUDING FRESH WATER, SEWER SURCHARGES, AND SEWER USE CHARGES FOR 100 LAUNDRIES

TABLE A-4

RANGES OF SEWER DISCHARGE STANDARDS FOR APPROXIMATELY 20 MUNICIPAL SEWER ORDINANCES

Item	Range Allowed
pH - units	4.5 - 10.5
Temperature - °F	<100 - 160
Grease - mg/l	<50 - 120
Phenol - mg/l	<0.02 - 10
Cyanide - mg/l	0 - 2
Zinc - mg/l	<2 - 15
Cadmium - mg/l	<0.02 - 5
Iron - mg/l	<10 - 50
Hexavalent Chromium - mg/l	<5 - 10
Copper - mg/l	<1 - 5
Mercury - mg/l	<0.0005 - 1.5
Nickel - mg/l	<0.1 - 10
Lead - mg/l	<0.1 - 5
Silver - mg/l	<0.1 - 5
Phosphate - mg/l	<40*
Barium - mg/l	<0.05 - 5*
Arsenic - mg/l	<0.05 - 5

* Uncommon

TABLE A-5

INDUSTRIAL AND LINEN LAUNDRY RESPONSES TO THE LAUNDRY INDUSTRY SURVEY

No.	Percentage Mix % Linen	% Indus.	Raw Water Cost - ¢/cu m	Sewer Charge ¢/cu m	Sewer Surcharge ¢/cu m	Water Consumption 1000 lpd	Wash Load 1000 kg/wk	Liters Consumed/ Kilogram laundered	Total Washroom Cost ¢/cu m	Location
1	--	100	8.1	3.4	0	129	18.2	35.4	11.4	Cal.
2	2	98	7.4	11.6	0	136	16.3	41.7	19.0	Wash.
3	35	65	3.7	11.1	0	568	74.8	38.3	14.8	Wash.
4	65	35	10.6	10.3	0	889	92.2	48.3	20.9	Ill.
5	98	2	4.8	--	--	1136	154.5	36.7	--	N.Y.
6	75	25	5.5	--	--	246	36.4	33.3	--	Mich.
7	--	100	8.2	3.4	2.6	1022	100.3	52.5	14.3	Ind.
8	90	10	8.7	--	--	269	42.0	32.5	--	Hawaii
9	--	100	5.5	4.2	0	--	26.5	--	9.8	Wash. D.C.
10	99	1	4.2	4.2	0	166	19.9	41.7	8.5	Ohio
11	90	10	4.0	1.3	0	386	57.3	34.2	5.2	—
12	100	--	7.4	8.7	0	--	90.9	--	16.2	Florida
13	85	15	6.1	2.1	0	--	41.0	--	8.2	Kan.
14	65	35	7.1	--	0	549	38.9	71.7	--	Cal.
15	90	0	5.8	2.6	0	114	22.5	25.0	8.5	Wash.
16	85	15	10.6	7.1	0	--	27.3	--	17.7	Minn.
17	10	90	5.7	0	0	220	33.3	32.5	--	Wis.
18	10	90	5.8	0	0	549	68.2	40.0	--	Wis.
19	100	--	8.7	4.2	0	95	113.6	41.7	12.9	Minn.
20	20	80	4.5	8.3	0	--	62.4	--	12.8	Ore.
21	--	100	14.5	6.6	12.4	--	102.3	--	33.5	Penn.
22	93	7	11.4	21.9	0	261	34.1	38.3	33.3	Penn.
23	5	95	9.8	7.1	4.6	1060	78.0	42.9	21.5	Ohio
24	--	100	6.4	0	--	--	40.9	--	--	Can.
25	4	96	5.3	--	--	484	68.2	35.4	--	Mich.

TABLE A-5, CONTINUED

INDUSTRIAL AND LINEN LAUNDRY RESPONSES TO THE LAUNDRY INDUSTRY SURVEY

No.	Percentage Mix % Linen	 % Indus.	Raw Water Cost ¢/cu m	Sewer Charge ¢/cu m	Sewer Surcharge ¢/cu m	Water Consumption 1000 lpd	Wash Load 1000 kg/wk	Liters Consumed/ Kilogram Laundered	Total Washroom Cost ¢/cu m	Location
26	--	100	7.1	0	0	95	8.5	55.8	7.1	N.J.
27	--	10	18.5	4.6	4.8	132	13.6	48.3	27.9	N.Y.
28	5	95	8.7	1.9	0.9	--	21.5	--	11.5	Tex.
29	94	6	3.2	5.2	0	--	28.5	--	8.4	--
30	100	--	11.6	0	0.5	424	63.6	33.3	12.2	Penn.
31	100	--	9.0	3.5	0	322	50.2	32.5	12.5	Mass.
32	--	100	7.3	0	--	201	36.0	27.5	--	Ill.
33	35	65	7.3	0	--	409	50.0	40.8	--	Ill.
34	--	100	14.5	7.0	12.4	--	57.3	--	33.9	Penn.
35	3	97	--	--	--	--	30.0	--	--	Penn.
36	--	100	8.2	--	--	--	39.1	--	--	Ind.
37	--	100	4.8	2.1	0	--	45.5	--	6.9	Missouri
38	--	100	9.0	3.5	0	136	15.2	45.0	12.5	Mass.
39	--	100	8.1	3.3	0	129	18.2	35.4	11.4	Mich.
40	6	94	4.0	4.2	0	488	55.9	43.7	8.2	Ohio
41	--	100	3.2	1.5	0	--	22.0	--	4.6	Texas
42	12	88	7.7	4.5	0	--	29.4	--	12.2	--
43	--	100	6.9	5.2	0	409	64.9	31.7	12.0	Ohio
44	--	100	3.4	0.5	0	--	18.2	--	4.0	Montana
45	96	4	6.7	6.3	0.5	405	40.9	49.1	13.6	Missouri
46	90	10	--	--	2.5	148	25.9	27.5	--	Ill.
47	--	100	12.2	0	0	--	40.9	--	12.2	Penn.
48	90	10	6.6	7.9	6.3	356	50.0	35.8	20.9	Colorado
49	100	--	7.4	7.1	0	435	63.6	34.2	14.5	Minn.

TABLE A-5, CONTINUED

INDUSTRIAL AND LINEN LAUNDRY RESPONSES TO THE LAUNDRY INDUSTRY SURVEY

No.	Percentage Mix % Linen	Percentage Mix % Indus.	Raw Water Cost - ¢/cu m	Sewer Charge ¢/cu m	Sewer Surcharge ¢/cu m	Water Consumption 1000 lpd	Wash Load 1000 kg/wk	Liters Consumed/ Kilogram Laundered	Total Washroom Cost ¢/cu m	Location
50	80	20	8.5	2.6	0	68	12.6	27.5	11.1	Wyo.
51	100	--	7.1	--	--	322	40.9	39.2	--	--
52	100	--	7.1	8.2	0	969	113.6	42.5	15.3	Fla.
53	75	25	4.5	1.1	0.1	291	30.0	49.1	5.7	N.Y.
54	90	10	10.8	2.0	0	295	36.4	40.8	12.8	Can.
55	97	3	8.2	--	--	420	66.5	31.7	--	--
56	90	10	7.7	12.7	5.5	685	93.2	36.7	25.9	Ga.
57	98	2	--	--	--	852	261.9	21.7	--	--
58	95	5	--	5.0	1.7	--	18.2	--	--	Mass.
59	100	--	3.7	--	--	855	102.3	41.7	--	--
69	96	4	7.1	--	0	568	90.9	31.2	--	Wis.
61	97	3	8.2	8.2	0	132	14.9	44.6	16.4	Ind.
62	90	10	6.6	--	--	--	21.5	--	--	Ariz.
63	7	93	6.8	--	--	--	55.9	--	--	Ariz.
64	75	25	6.8	1.3	0	220	30.2	36.2	7.7	Neb.
65	95	5	7.8	1.6	0	515	68.2	37.5	9.4	Cal.
66	90	10	6.6	--	--	348	27.3	65.0	--	Cal.
67	90	10	10.6	6.9	0	330	74.1	35.0	7.4	Minn.
68	85	15	18.2	14.5	4.2	197	42.0	22.5	37.0	Ill.
69	85	15	9.5	1.6	1.3	443	69.5	31.7	12.4	Tex.
70	100	--	7.1	--	2.2	643	--	--	--	Tex.
71	6	94	6.8	6.8	--	140	14.5	48.3	--	--
72	--	100	11.9	2.4	1.6	--	18.7	--	15.9	Tex.
73	2	98	5.8	6.9	5.8	556	77.3	35.8	18.5	Ind.
74	--	100	5.5	--	--	522	66.0	38.7	--	--
75	--	100	--	--	--	--	45.5	--	--	Okla.

TABLE A-5, CONTINUED

INDUSTRIAL AND LINEN LAUNDRY RESPONSES TO THE LAUNDRY INDUSTRY SURVEY

No.	Percentage Mix % Linen	Percentage Mix % Indus.	Raw Water Cost ¢/cu m	Sewer Charge ¢/cu m	Sewer Surcharge ¢/cu m	Water Consumption 1000 lpd	Wash Load 1000 kg/wk	Liters Consumed/ Kilogram Laundered	Total Washroom Cost ¢/cu m	Location
76	--	100	5.8	--	--	--	11.8	--	--	Ariz.
77	100	--	7.3	3.7	0	47	24.6	23.3	11.0	Kent.
78	--	100	6.6	5.3	0	180	19.8	45.0	9.9	Kent.
79	15	85	6.1	4.0	0	--	11.8	--	10.0	Kent.
80	45	55	4.9	8.2	8.7	541	45.5	60.0	21.8	Vir.
81	45	55	4.0	2.1	0	--	18.2	--	6.1	Colo.
82	--	100	6.6	--	--	--	182.2	--	--	Can.
83	35	65	7.9	2.1	0	454	48.7	45.0	10.0	Tenn.
84	1	99	6.1	6.1	15.9	242	49.5	24.2	28.0	Mich.
85	10	90	5.8	10.8	0	125	21.8	28.3	16.6	Ore.
86	15	85	13.2	4.8	0	378	46.5	40.0	18.0	N.Y.
87	10	90	9.0	--	--	79	10.7	37.5	--	N.Y.
88	75	25	12.4	6.1	0	--	24.5	--	18.5	Ark.
89	--	100	7.9	29.6	0.8	117	18.2	32.5	38.3	Penn.
90	88	12	7.9	--	--	284	45.5	31.7	--	--
91	--	100	7.4	1.8	--	--	84.3	--	--	N.Y.
92	--	100	4.0	1.8	0	545	60.5	45.0	5.8	Penn.
93	--	100	5.2	4.1	0	333	45.5	36.7	9.2	N.Y.
94	15	85	6.1	--	--	276	47.9	29.2	--	Mass.
95	60	40	4.0	4.5	0	102	9.5	53.3	8.5	Fla.
96	70	30	10.0	7.4	0.5	492	58.2	42.5	18.0	Md.

APPENDIX B

ANALYTICAL PROCEDURES AND BENCH TEST METHODS

ANALYTICAL INSTRUMENTS AND APPARATUS

pH meter: Beckman Model 552
Beckman Instruments Incorporated
Fullerton, California

BOD Incubator: Labline No. 3554B Incubator
Lab-Line Instruments, Inc.
Melrose Park, Illinois

Analytical Balance: Type H10
Mettler Instruments Corporation
Hightstorm, New Jersey

Spectrophotometer: Coleman Model 14
Coleman Instrument Company
Maywood, Illinois

Atomic Absorption Spectrophotometer: Perkin Elmer Model 403
Perkin Elmer Corp.
Norwalk, Connecticut

TOC Analyzer: Beckman 915 TOC Analyzer
Beckman Instruments Co.
Fullerton, California

Turbidimeter: Hach Model 2100A Turbidimeter
Hach Chemical Co.
Ames, Iowa

ANALYTICAL PROCEDURES AND ANALYSES

The following analyses were performed according to Standard Methods for the Examination of Water and Wastewater, (6) (Standard Methods) and Methods for the Chemical Analysis of Water and Waste (18) (WQO).

Total Solids - Method A, p. 535, Standard Methods; The amount of sample used was determined by weight rather than by volume; approximately 20 grams of sample was used for total solids.

Suspended Solids - Method C, p. 537, Standard Methods; Reeve-Angel 934AH glass fiber discs were used in place of the mats prepared by using asbestos fibers. Filter disc is dried in aluminum tin at 103°C.

Also used filtration through a 47 mm membrane filter (0.45μ) using Millipore filter holder. Filter is dried in aluminum tin at 103°C. Only used this method for a few samples.

Biochemical Oxygen Demand - p. 489, Standard Methods; BOD tests could often not be performed until several days after sample collection. Raw sewage was used as a seed (1 ml volume). The dissolved oxygen was measured by a Yellow Springs instrument DO probe, Yellow Springs, Ohio. (Method F., p. 489 of Standard Methods.)

Alkalinity - p. 370, Standard Methods; Electrometric titration to pH 8.3 and 3.7

Total Coliform - p. 679, Standard Methods, Method A. Millipore Membrane filter method for total coliform

Color - p. 160, Standard Methods; Helige Chromatron - comparison against glass discs calibrated with platinum-cobalt standards

Cyanide - p. 399, Standard Methods; The sample is pretreated by distillation and analyzed for cyanide by titration or colorimetrically, depending upon the concentration.

Grease - p. 409, Standard Methods; Soxhlet extraction of a filtered sample with hexane.

Kjeldahl Nitrogen - p. 244, Standard Methods; Digestion of the sample followed by distillation and titration. This measures both organic nitrogen and ammonia.

pH - p. 276, Method A, Standard Methods, pH meter measurement using a Beckman Model SS2 pH meter

Volatile Total Solids - p. 292, (Method D) and 536 (Method B), Standard Methods; Residue and dish ignited at 550°C.

Volatile Suspended Solids - p. 292 (Method D) and p. 536 (Method B) Standard Methods; The residue and filter from the glass fiber filter suspended solids method are transferred to a crucible for ignition.

Total Hardness - p. 76, WQO, EDTA titration using Hach chemical as specified by WQO.

Ammonia Nitrogen - p. 134, WQO, Distillation at pH 9.5 followed by Nesslerization or titration. There is more chance of measuring some amines as NH_3 with this method, but less trouble in testing samples containing large amounts of calcium.

Total Phosphorus - p. 242, WQO, p. 231, Method A, 12th Edition, Standard Methods, (1965). Sample is digested with persulfate (WQO method) and phosphate measured by ANS procedure (Standard Methods).

Sulfate - p. 286, WQO; Turbidimetric method using Hach SulfaVer.

Turbidity - p. 308, WQO; using Hach Model 2100A turbidimeter.

TOC - p. 221, WQO; Bechman Model 915 TOC analyzer.

The following analyses were performed according to the methods listed in Analytical Methods for Atomic Absorption Spectrophotometry, Perkin Elmer Corp. (19), equivalent to the mentioned WQO method. The digestion procedure described on pages 86-89 of Methods for Chemical Analysis of Water and Waste was used for all metals (18). All metals were measured by atomic absorption spectroscopy.

Calcium - p. 102, WQO

Cadmium - p. 101, WQO

Total Chromium - p. 104, WQO

Copper - p. 106, WQO

Iron - p. 108, WQO

Lead - p. 110, WQO

Magnesium - p. 112, WQO

Manganese - p. 114, WQO

Mercury - p. 121, WQO, Flameless atomic absorption

Nickel - Perkin Elmer Analytical Methods

Potassium - p. 115, WQO

Sodium - p. 118, WQO

Silicon- Perkin Elmer, Analytical Methods using the nitrous oxide flame

Zinc - p. 120, WQO

Tin - Perkin Elmer Analytical Methods

The following analyses were performed according to the procedures listed:

Specific Gravity - hydrometer

Viscosity - Brookfield viscometer

Phenol - Hach Catalog No. 10, p. 52. Chemical removal of interference followed by treatment with 4- aminoantipyrine for color development. Color development part is based on the following procedures: Standard Methods, p. 504 and 507, or WQO, p. 232.

Analysis for Dissolved Matter - The analysis for dissolved matter (i.e. BOD, TOC) was obtained by filtering the sample through a millipore filter (0.45 μ) and then performing the appropriate analysis (BOD, TOC) on the filtrate. If the sample contained gross amounts of solids which would rapidly blind the millipore filter disc, the sample was prefiltered through SS-597 filter paper. The filtrate from this prefiltraiton was then filtered through the millipore disc as described above.

DISSOLVED-AIR FLOTATION TEST PROCEDURE

The rate of separation of the suspended solids from a waste is useful in the design of industrial waste treatment equipment. Rate of separation data may be conveniently obtained in the laboratory from treatment tests performed on the waste in question. Generally, the procedure used in obtaining rate-of-separation data is to observe the solids-liquid interface and record its travel with time. The test procedure for performing this test follows.

A. Dissolved-Air Flotation

In the tests using dissolved-air flotation, the rate of rise of the major portion of the solids is recorded. At times the solids-liquid interface may be vague and good judgment may have to be exercised in following this interface. Care should be taken to avoid following the interface formed by the air bubbles alone. In general, this interface lags behind the solids-liquid interface.

A suggested procedure for the performance of laboratory flotation tests and the equipment needed is as follows:

1. Equipment

   a. Flotation pressure cell
   b. Graduated cylinder of one liter capacity containing an effluent sampling nozzle.
   c. Tire pump or source of compressed air
   d. Gooch crucibles for suspended solids determinations
   e. Stop watch

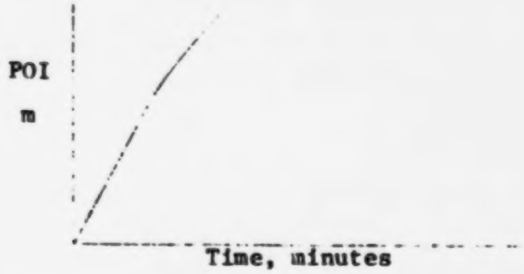
2. Flotation Test Procedure

   a. Record waste temperature, pH, operating pressure, recycle rate, and flotation detention time.
   b. Record rate of separation data. The form shown below is suggested in obtaining the rate of separation data.

   The ultimate data desired is the position of the interface at various intervals throughout the test. The column below labeled "Volume" is used as a convenient means of obtaining the position of the interface at any given time. For example, in the hypothetical case shown below, a liter graduate was used in the test. At the beginning of the test, the solids-liquid interface is at the bottom of the graduate or at zero volume. As flotation progresses, the solids-liquid interface moves progressively up the height of the graduate. The position of the interface at any given time may be conveniently obtained using the appropriate graduation mark on the liter cylinder as a reference. After the flotation test, the graduation marks may be converted to the actual height by measurement.

Time, min.	Volume, ml	POI (position of interface), meters
0	0	0
1	100	0.035
2	350	0.125
3	500	0.179
4	650	0.233
5	800	0.288
6	950	0.342
7	950	0.342
8	950	0.342

The data obtained are plotted using Time as the abscissa and POI in meters as the ordinate.



The slope of the straight line portion of the curve represents the rate of particle rise.

During flotation it should be noted whether settling of solids took place. Note observation.

c. Record the floated scum volume obtained immediately before obtaining a sample of the effluent.

d. Obtain sample of effluent five minutes after flotation is started for the appropriate analyses. Repeat the flotation and obtain another sample of effluent for analysis after an eight minute detention period.

e. If possible, a small portion of the floated scum should be analyzed for total solids content.

BUCHNER FUNNEL TEST PROCEDURE

The test equipment is shown in Figure B-1.

1. Moisten filter paper (Whatman #4) and place it in the Buchner funnel. Apply a vacuum to obtain a seal. Empty water collected in filtrate receiver.

2. Analyze the sludge to be filtered for solids content.

3. Measure a volume of sludge that will provide a 3 mm to 6 mm thick cake.

4. Select the conditioning chemicals to be utilized and add a predetermined amount to the sludge to be conditioned. This should be reported as pounds chemical/ton sludge dry solids.

5. Agitate the volumetric flask vigorously and allow the sludge to sit two minutes. Always agitate the sludge approximately the same amount for any one test series.

6. Add the sludge to the funnel and quickly apply vacuum. As soon as vacuum is applied, start the stopwatch. A vacuum reservoir may be needed to hold a constant vacuum.

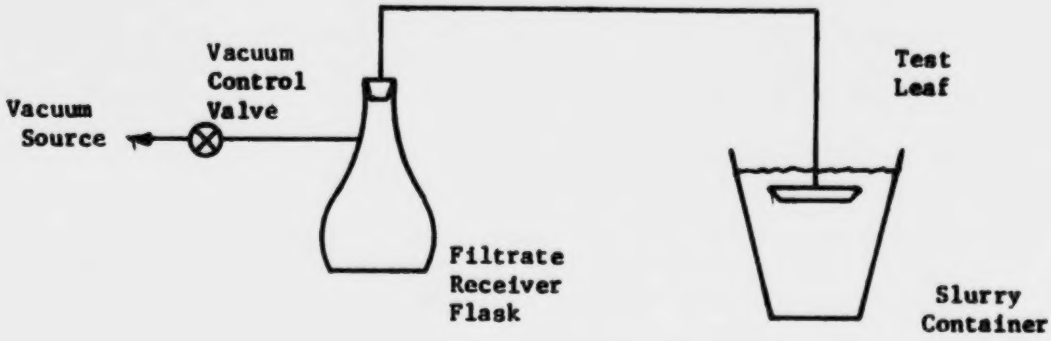
7. Take filtrate volume readings with respect to time.

8. Continue the test until the cake cracks, or no filtrate is deposited for a one minute interval. Usually five minutes is sufficient. Be sure the cake edges do not shrink from the sides of the Buchner funnel. If it does, tamp the edges of the cake to maintain a seal.

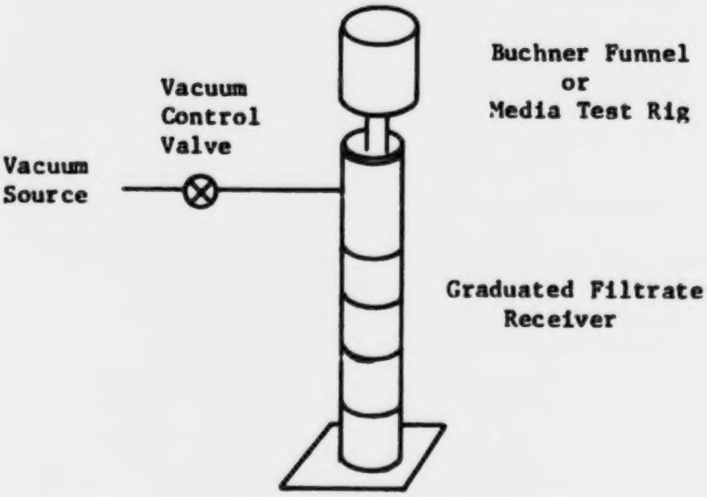
9. Sample cake for total solids.

10. Record filtrate temperature, vacuum level, and cake thickness.

11. Plot a curve of time/volume filtrate vs. volume filtrate and record the slope of the curve. The slope recorded should include only the linear portion of the curve.


Vacuum Source
Vacuum Control Valve
Filtrate Receiver Flask
Test Leaf
Slurry Container

LEAF TEST EQUIPMENT


Buchner Funnel or Media Test Rig
Vacuum Control Valve
Vacuum Source
Graduated Filtrate Receiver

BUCHNER FUNNEL AND MEDIA EQUIPMENT

FIGURE B-1
TEST EQUIPMENT

12. Calculate specific cake resistance from the formula:

$$\alpha = 2PA^2b/\mu\omega$$

where α = specific resistance in sec^2/gm
P = vacuum level in gm/sq cm
A = area of Buchner funnel in sq cm
b = slope of t/v vs. v curve in sec/cm^6
μ = viscosity in Poise
$\omega = 1/[Ci/(100-Ci)) - (Cf/(100-Cf))]$

Ci = initial sludge moisture (%)
Cf = moisture concentration in cake (%)

13. Repeat steps 1 through 12 for several dosages of the same chemical.

14. Plot specific resistance vs. chemical dosage. The minimum point obtained on the curve is the optimum chemical dosage for the chemical tested.

FILTER MEDIA SELECTION TEST PROCEDURE

1. Select a cloth for testing in accordance with information available on chemical and physical conditions, sludge type and properties, and parameter qualities desired.

2. Moisten the cloth and place it in a Buchner funnel. Apply a vacuum to obtain a seal.

3. Analyze sludge sample for solids content.

4. Measure a volume of sludge equivalent to a cake thickness of 3 mm to 6 mm.

5. Condition the sludge with the optimum chemical dosage determined from the Buchner funnel test as described in that test procedure.

6. Add the sludge to the Buchner funnel. Applv a vacuum of about 50 cm Hg and start the stopwatch.

7. Measure the time to collect 100 cc of filtrate, 150 cc of filtrate, and 200 cc of filtrate. Discontinue test after 5 minutes.

8. Remove the cloth and measure cake thickness.

9. Note cake release as follows:

excellent - cake peels off medium in pieces with slight amount of spatula aid.

fair - cake must be taken off medium piece by piece with spatula

poor - cake will not come off medium even with maximum spatula use. Some solids left on medium.

10. Analyze the cake for solids content and the filtrate for suspended soids.

11. Wash the filter cloth on both sides with an intense water spray for 5 seconds.

12. Determine if any solids are deposited in the cloth interstices by eye or microscopic evaluation.

13. Repeat steps 1 to 12 three times utilizing the same sample medium.

14. Run a standard test on the sludge at optimum chemical dosage using #4 Whatman filter paper and a 50 cm Hg vacuum.

VACUUM FILTER LEAF TEST PROCEDURE

The test equipment is shown in Figure B-1.

1. Condition 2-4 liters of sludge according to Buchner funnel test results.

2. Place cloth selected from media screening test on the filter leaf and attach leaf hose to filtrate receiver.

3. Crimp the hose connecting the leaf to the vacuum source and set vacuum to desired level with the bleeder valve.

4. Immerse the leaf in the sludge so that the surface of the leaf is two to three inches below the sludge level. Release the hose and start the stopwatch simultaneously.

5. Keep the leaf submerged for a predetermined pickup time obtained from preliminary tests. For thin sludges, move the leaf slowly in a horizontal plane with a circular wrist movement at a rate of 6 rpm. In thick sludges, the leaf should remain stationary. Keep thin sludges mixed with a small mixer. Thick sludges should be thoroughly mixed prior to the test.

6. At the end of the pickup time, the leaf is rotated out of the bucket.

7. The leaf is then held with the cake upward for the duration of the drying cycle. At the end of this time, vacuum is released. Adjust the vacuum as much as needed during the dry time to maintain vacuum level. Allow all filtrate to drain from the hose to the filtrate receiver.

8. Remove the cake from the filter leaf by blowing into leaf hose and dislodging it with a spatula. Analyze the cake for total solids. Note cake discharge and thickness.

9. Analyze filtrate for suspended solids, and record the filtrate volume.

10. Repeat steps 1-9 twice more on the same sample to determine if the results are reproducible.

11. Analyze solids content of remaining sludge. Two to four tests may be run on the same sample.

Preliminary Testing

In initial tests, submerge test leafs for various perious of time and note at what time cake sloughing takes place, i.e. sludge will no longer build up uniformly, but falls off when leaf is removed from bucket. This is the maximum pickup time. The minimum pickup time is the time required to produce a cake thick enough to discharge.

Utilizing the maximum pickup time determined above, perform a leaf test and allow the cake to dry until it cracks or shrinks away from the edges of the leaf. This represents the maximum drying time. Run the remainder of the leaf tests according to steps 1-11 in the range of these established pickup and drying times.

FLOCCULATION JAR TEST PROCEDURE

1. Measure 50 ml to 100 ml into a 100 ml graduated cylinder and add a predetermined dosage of the chemical selected.

2. Invert the cylinder three times, keeping the palm on the top of the cylinder. (This is rapid mix.)

3. Add any additional chemicals in the order desired and repeat step 2.

4. Gently swirl the graduated cylinder with the wrist for a predetermined time interval. Observe the floc formation.

5. Repeat steps 1 to 4 for various chemical dosages, and compare the graduated cylinders visually to determine optimum chemical dosage. Floc size, supernatant clarity, and rate of floc formation all help in determining the optimum chemical dosage.

6. Utilize any other chemicals desirable.

DIATOMACEOUS EARTH PRECOAT VACUUM FILTRATION BENCH TEST PROCEDURE

1. Utilize the leaf test equipment shown in Figure B-1 with a suitable cloth support medium.

2. Provide two extra pans with continuous mixing, one with a 3% diatomaceous earth slurry and the other with a clay suspension or suspension of other blinding substances.

3. Insert the filter leaf into the DE slurry and apply a 12 to 24 cm Hg vacuum. Obtain a 20 mm to 40 mm thickness of DF on the test leaf. Cut away an edge of the cake to form a circular area of a known diameter. It will look like a small plateau above the rest of the filter aid. This is the desired filtration surface.

4. Insert the filter leaf into the clay suspension and leave it until no filtrate is deposited, thus blinding off the whole leaf. Scrape away the clay from the plateau of the filter leaf with a spatula to expose the filtration surface.

5. Perform a leaf test with this filter leaf as described in the vacuum filter leaf test procedure beginning with step 3. Eliminate the circular wrist movement, however, and hold the leaf stationary. Proceed to step 7 of that procedure.

6. Measure the final filtrate volume, and scrape off the picked up solids to expose fresh filter surface for the next test. Analyze the filtrate for total solids and repeat steps 5 and 6.

7. Analyze the suspension to be filtered and filter aid cuttings for total ash to calculate the amount of filter aid required for a large system. Try different DE grades to optimize filtrate clarity and filtration rate.

NOTE: Always keep a vacuum on the filter leaf to avoid losing the precoat. Preliminary testing can be utilized to determine what length pickup time is required.

APPENDIX C

OPERATING DATA AND SAMPLE ANALYSES

TABLE C-1

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 15, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/l)	Total Solids (mg/l)	pH (units)	Soluble TOC (mg/l)	Suspended Solids (mg/l)	Volatile Sus. Solids (mg/l)	Supplies Added
364 kgs	Flush	1340	12,500	13,233	8.4	3213	7700		
(800 lbs)	Suds	420	77,000	86,175	12.9				X
Shop Towels	Carryover	420	59,000	101,045	13.0				
	Rinse 1	1340	--	--					
	Rinse 2	1340	24,500	42,636	12.6				
	Rinse 3	1340	13,000	31,020	12.9				
	Rinse 4	1340	8950	15,931	12.9	1780			
	Rinse 5	1340	7500	11,132	12.7				
	Rinse 6	1340	4150	7985	12.5				
	Rinse 7	1340	2550	4660	12.1		5110		
	Rinse 8	1340	1600	3480	12.1				
	Rinse 9	1340	900	2148	11.8				
	Rinse 10	1340	700	1554	11.6				
	Dye	1340	750	3797	10.9				X
	Cold Rinse	1340	400	1661	10.4	40	455	320	
kgs/100 kgs Laundered	--	--	44.6	73.1	--	--	--	--	

TABLE C-1, CONTINUED

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 15, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Soluble TOC (mg/1)	Suspended Solids (mg/1)	Volatile Sus. Solids (mg/1)	Supplies Added
182 kgs (400 lbs Printer's Towels	Flush	655	17,750	14,644	7.8	8070	2150	1640	X
	Suds	216	98,000	88,286	13.2				
	Carryover	216	83,500	81,803	13.2				
	Rinse 1	655	21,500	40,224	13.1				
	Rinse 2	655	16,400	25,420	12.7				
	Rinse 3	655	12,300	16,607	12.8				
	Rinse 4	655	6050	11,581	12.5				
	Rinse 5	655	5900	6360	12.4				
	Rinse 6	655	1450	4134	12.3				
	Rinse 7	655	1000	2839	12.0				
	Rinse 8	655	650	1802	11.8				
	Rinse 9	655	400	1245	11.4				
	Rinse 10	655	400	1005	10.9				
	Rinse 11	655	225	812	10.6				
	Cold Rinse	655	200	663	10.3	98	272		
kgs/100 kgs Laundered	--	--	41.9	66.2	--	--	--	--	

TABLE C-1, CONTINUED

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL DISCHARGE DATA MARCH 16, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	Soluble TOC (mg/1)	pH (units)	Silica as SiO_2 (mg/1)	Sus. Solids (mg/1)	Volatile Sus. Solids (mg/1)	Supplies Added
364 kgs (800 lbs) Printer's Towels	Flush[1]	1340	8500	7444	3000_e	8.0		2010		
	Suds	420	100,000	74,180	30,700	13.1		5040	5555	X
	Carryover	420	58,000	49,258	23,125	13.2		6320		
	Rinse 1[2]	1340	9125	28,136	2063	12.9	1800	1898		
	Rinse 2	1340	9000	19,574	1875	12.8		1510		
	Rinse 3	1340	4150	8933	4050	12.6		690		
	Rinse 4	1340	5000	10,727	1300	12.7		2425	2085	
	Rinse 5	1340	2400	5632	655	12.5		910		
	Rinse 6	1340	1100	3097	520	12.2		640		
	Rinse 7	1340	800	2282	391	12.0		420		
	Rinse 8	1340	575	1620	251	11.7		380		
	Rinse 9	1340	600	1735	215	11.5		295		
	Rinse 10	1340	460	1436	235	11.5		273		
	Cold Rinse[3]	1340	520	1231	200_e	11.2		580	505	
kgs/100 kgs Laundered	--	--	33.9	48.2	11.7	--		5.75	--	

[1] Grease, mg/1 - 3345
[2] Alkalinity, mg/1 as $CaCO_3$ - 7150
[3] Grease, mg/1 - 202

e = estimated

TABLE C-1, CONTINUED

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 16, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Soluble TOC (mg/1)	Sus. Solids (mg/1)	Volatile Sus. Solids (mg/1)	Supplies Added
182 kgs (400 lbs) Dust Mops	Flush	655	990	3730	9.0	385	1410	1050	
	Suds	216	22,500	57,878	13.1				X
	Carryover	216	18,000	49,144	13.1				
	Rinse 1	655	7600	31,980	13.0				
	Rinse 2	655	4350	16,991	12.8				
	Rinse 3	655	2600	7033	12.6				
	Rinse 4	655	1750	3904	12.2				
	Rinse 5	655	900	2507	12.0				
	Rinse 6	--	--	--	--		--	--	
	Dye	655	900	5681	11.7				X
	Rinse 7	655	768	2912	11.2	214	750		
kgs/100 kgs Laundered			12	39.7	--	--	--	--	

TABLE C-1 CONTINUED

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 16, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Sus. Solids (mg/1)	Volatile Sus. Solids (mg/1)	Soluble TOC (mg/1)	Supplies Added
182 kgs	Flush	655	910	3731	9.0	1420		520	
(400 lbs)	Suds[1]	216	12,500	40,543	13.2				X
Dust Mops	Carryover	216	15,250	50,591	13.1				
	Rinse 1[2]	655	9800	32,740	12.9				
	Rinse 2	655	5950	8940	12.8				
	Rinse 3	655	4920	10,451	12.7	2990	2290	775	
	Rinse 4	655	2150	6236	12.4				
	Rinse 5	655	1460	3291	12.1				
	Rinse 6	655	850	2201	11.9				
	Dye	655	650	3686	11.3				X
	Rinse 7	655	304	1987	10.9	685		69	
kgs/100 kgs Laundered	--	--	13.0	40.9	--	--	--		

[1] Alkalinity = 20,313 mg/1 as $CaCO_3$
[2] Grease = 2,300 mg/1 as SiO_2

TABLE C-1, CONTINUED

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 16, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Soluble TOC (mg/1)	Sus. Solids (mg/1)	Volatile Sus. Solids (mg/1)	Supplies Added
364 kgs (800 lbs) Printer's Towels	Flush	1340	1900	7263	12.6	750	1385		
	Suds	420	45,800	79,900	14.0				X
	Carryover	420	43,500	60,108	13.4				
	Rinse 1	1340	8250	35,127	13.1				
	Rinse 2	1340	5250	23,413	13.0				
	Rinse 3	1340	2700	12,277	12.9				
	Rinse 4	1340	1600	7850	12.7	694	1630		
	Rinse 5	1340	570	4185	12.5				
	Rinse 6	1340	510	2596	12.2				
	Rinse 7	1340	480	1521	11.8				
	Rinse 8	1340	160	1224	11.2				
	Rinse 9	1340	140	885	10.6				
	Rinse 10	1340	80	625	10.3				
	Cold Rinse	1340	236	635	10.0	18	440	405	
kgs/100 kgs Laundered			18.4	52.2					

TABLE C-1, CONTINUED

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 16, 1973

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	Silica As SiO$_2$ (mg/1)	pH (units)	BOD (mg/1)	Soluble TOC (mg/1)	Supplies Added
364 kgs	Flush[1]	1340	18,000	51,087	--	8.3	<100	23	
(300 lbs)	Suds	420	43,500	86,175	7200	13.0	7960		X
Shop Towels	Carryover	420	30,000	80,725	5000	13.1	6825		
	Rinse 1[2]	1340	13,800	38,746	3000	12.7	4500		
	Rinse 2	1340	4000	13,031	920	12.5	1820		
	Rinse 2	1340	2000	8649	660	12.3	900		
	Rinse 4	1340	850	3368	325	12.0	380		
	Rinse 5	1340	730	2261	220	11.6	200		
	Rinse 6	1340	470	1740	145	11.2	100$_e$		
	Rinse 7	1340	810	1233	70	10.6	50$_e$		
	Rinse 8[3]	1340	236	818	62	10.4	50$_e$		
	Rinse 9	1340	136	609	39	10.1	50$_e$	20	
	Dye	1340	288	2252	44	9.9	300$_e$		X
	Cold Rinse[4]	1340	194	1277	30	9.7	200$_e$	13	
kgs/100 kgs Laundered	--	--	23.9	65.3	27.5	--	4.9		

^{e} = estimated

[1] Grease, mg/1 = 18,000

[2] Alkalinity as CaCO$_3$ = 6300 mg/1

[3] Suspended Solids, mg/1 = 515

[4] Grease, mg/1 = 191

TABLE C-1, CONTINUED

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 16, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	BOD (mg/1)	Sus. Solids (mg/1)	Volatile Sus. Solids (mg/1)	Supplies Added
364 kgs	Suds	420	4,800	16,227	12.0		1160	1060	X
(800 lbs)	Rinse 1	1340	3220	9588	11.7				
New Wipers	Rinse 2	1340	2720	8553	11.6				
	Rinse 3	1340	1720	5395	11.4				
	Rinse 4	1340	1084	3388	11.2				
	Rinse 5	1340	652	2582	10.9	850			
	Rinse 6	1340	676	2696	10.8	305			
kgs/100 kgs Laundered	--	--	4.3	13.7	--	--			

TABLE C-1, CONTINUED

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL

DISCHARGE DATA

MARCH 16, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Grease (mg/1)	Sus. Solids (mg/1)	Volatile Sus. Solids (mg/1)	Supplies Added
346 kgs	Flush	1340	3250	56,809	8.9	9878	5420		
(800 lbs)		420							
Printer's	Suds	420	46,000	50,797	13.2				
Towels	Carryover	1340	14,625	24,295	13.0				X
	Rinse 1	1340	8500	17,856	12.9				
	Rinse 2	1340	26,200	23,695	12.9				
	Rinse 3	1340	7000	9587	12.7				
	Rinse 4	1340	5200	9530	12.7				
	Rinse 5	1340	3100	7250	12.4				
	Rinse 6(1)	1340	1820	4280	12.3		1550	1390	
	Rinse 7	1340	1550	4108	12.3				
	Rinse 8	1340	840	2799	12.1				
	Rinse 9	1340	720	2334	11.9				
	Rinse 10	1340	1210	3340	11.9				
	Rinse 11	1340	550	1838	11.5				
	Rinse 12	1340	260	1177	11.4	166			
kgs/100 kgs Laundered	--	--	29.3	62.0	--	--	--	--	

(1) Soluble TOC, mg/1 = 190

TABLE C-1, CONTINUED

INDUSTRIAL LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 23, 1972

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Suspended Solids (mg/1)	Supplies Added
364 kgs (800 lbs) Printer's Towels	Flush	1340	529	655	9.2		
	Suds	420	17,350	49,600	12.6	8665	X
	Carryover	420	11,400	30,252	12.40		
	Rinse 1	1340	4950	9942	11.85		
	Rinse 2	1340	3125	4855	11.8		
	Rinse 3	1340	3220	3825	11.65		
	Rinse 4	1340	1690	2190	10.9		
	Rinse 5	1340	2376	2465	11.2		
	Rinse 6	1340	1420	1534	10.6		
	Rinse 7	1340	1006	1243	10.2		
	Rinse 8	1340	1082	1159	9.95		
	Rinse 9	1340	638	963	9.65		
	Rinse 10	1340	696	585	9.6		
	Rinse 11	1340	522	665	9.45		
	Rinse 12	1340	477	695	9.4		
	Rinse 13	1340	388	633	9.3	240	
	Rinse 14	1340	268	303	9.1		
kgs/100 kgs Laundered	--	--	11.5	20.9			

TABLE C-2

UNIFORM LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 23, 1972

Article Laundered	Operation	Water Volume (liters)	TOC (mg/l)	Total Solids (mg/l)	pH (units)	Suspended Solids (mg/l)	Supplies Added
364 kgs (800 lbs) Synthetic Shirts	Suds	420	4090	21,916	12.35	3120	X
	Flush	1340	1706	6990	11.95		
	Suds	420	1822	12,755	12.75		X
	Rinse 1	1340	804	5016	12.4		
	Rinse 2	1340	350	2423	12.1		
	Rinse 3	1340	200	1212	11.75		
	Rinse 4	1340	130	794	11.25		
	Rinse 5	1340	96	520	10.4	86	
	Rinse 6	1340	66	460	10.1		
	Sour	420	90	612	8.1		X
	Starch	408	3109	7515	7.55		X
kgs/100 kgs Laundered	--	--	2.3	11.4	--	--	--

TABLE C-2, CONTINUED

UNIFORM LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 24, 1972

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Suspended Solids (mg/1)	Supplies Added
182 kgs	Flush	655	127	535	7.9		
(400 lbs)	Suds	216	730	11,984	12.8	147	X
White	Carryover	216	636	8339	12.7		
Uniforms	Flush	655	418	3842	12.45		
	Suds	216	449	3216	12.3		
	Bleach	216	395	4264	12.3		X
	Rinse 1	655	510	4319	11.75		
	Rinse 2	655	164	1544	11.65		
	Rinse 3	655	94	766	11.2		
	Rinse 4	655	155	1033	10.5		
	Rinse 5	655	132	605	10.6		
	Rinse 6	655	64	374	9.5	60	
	Sour	216	48	946	4.3		X
kgs/100 kgs Laundered			0.9	6.8	--	--	

TABLE C-2, CONTINUED

UNIFORM LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 24, 1972

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Suspended Solids (mg/1)	Supplies Added
364 kgs	Flush	1340	1691	3927	7.35		
(800 lbs)	Suds	420	5022	17,266	12.65	4990	X
Rugs	Carryover	420	7403	17,704	12.65		
	Rinse 1	1340	4826	12,250	12.50		
	Rinse 2	1340	4826	9885	12.35		
	Rinse 3	1340	4323	9339	12.3		
	Rinse 4	1340	3534	8521	12.25		
	Rinse 5	1340	2098	3318	11.8		
	Rinse 6	1340	960	1890	11.3		
	Rinse 7	1340	373	1093	10.6	385	
	Oil Treatment	420	1548	3131	7.9		X
kgs/100 kgs Laundered			9.9	22.9	--	--	

TABLE C-2, CONTINUED

UNIFORM LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 24, 1972

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Grease (mg/1)	Suspended Solids (mg/1)	Supplies Added
182 kgs (400 lbs) Colored Uniforms	Suds	216	5034	15,931	12.5	1700	860	x
	Carryover	216	5344	12,448	12.45			
	Rinse 1	655	1856	4383	12.1			
	Rinse 2	655	586	1888	11.6			
	Rinse 3	655	259	765	10.85			
	Rinse 4	655	117	429	10.15			
	Rinse 5	655	83	498	9.7			
	Rinse 6	655	57	360	9.5		176	
	Sour	216	50	1684	4.7	86		X
	Starch	132	1938	4331	4.85			X
kgs/100 kgs Laundered			2.5	6.9	--	--	--	

TABLE C-2, CONTINUED

UNIFORM LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 24, 1973

Article Laundered	Operation	Volume (liters)	TOC (mg/1)	Solids (mg/1)	pH (units)	Solids (mg/1)	Supplies Added
182 kgs (400 lbs) Shirts	Suds	216	6314	21,112	13.1	810	X
	Carryover	216	3591	13,916	12.95		
	Rinse 1	655	1473	5441	12.55		
	Rinse 2	655	875	2743	12.2		
	Rinse 3	655	310	1436	11.9		
	Rinse 4	655	336	944	11.3		
	Rinse 5	655	92	569	10.5		
	Rinse 6	655	64	524	10.05	126	
	Sour	216	66	1513	4.9		X
	Starch	132	2800	7096	4.9		X
kgs/100 kgs Laundered			2.5	9.2	--	--	

TABLE C-2, CONTINUED

UNIFORM LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 24, 1972

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1	Total Solids (mg/1)	pH (units)	Grease (mg/1)	Sus. Solids (mg/1)	Supplies Added
384 kgs (800 lbs)	Break	420	6396	21,783	12.8	2520	2780	X
Synthetic Pants	Carryover	420	3520	13,429	12.7			
	Break	420	1604	7220	12.55			
	Rinse 1	1340	958	3392	12.3			
	Rinse 2	1340	649	1781	12.05			
	Rinse 3	1340	379	1763	11.75			
	Rinse 4	1340	264	1342	11.5			
	Rinse 5	1340	214	1145	11.25			
	Rinse 6	1340	79	534	10.2		110	
	Sour	420	78	1011	5.15	321		X
	Starch	412	575	1833	6.7			X
kgs/100 kgs Laundered	--	--	2.3	8.9	--	--	--	

TABLE C-2, CONTINUED

UNIFORM LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 24, 1972

Article Laundered	Operation	Water Volume (liters)	TOC (mg/l)	Total Solids (mg/l)	pH (units)	Suspended Solids (mg/l)	Supplies Added
182 kgs	Suds	216	4,644	16,125	12.7	2090	X
(400 lbs)	Carryover	216	2948	10,538	12.5	1214	
Coveralls	Rinse 1	655	1052	4250	12.2	530	
	Rinse 2	655	552	2248	11.85	376	
	Rinse 3	655	260	1232	11.45	242	
	Rinse 4	655	125	797	10.6	173	
	Rinse 5	655	86	589	10.1	157	
	Rinse 6	655	67	469	9.7	128	
	Sour	216	44	1087	4.95	247	X
	Starch	132	626	2077	6.9	446	X
kgs/100 kgs Laundered			1.7	6.9	--	1.1	

TABLE C-3

LINEN LAUNDRY SURVEY WASH WHEEL

DISCHARGE DATA

MARCH 16, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Sus. Solids (mg/1)	Volatile Sus. Solids (mg/1)	Supplies Added
364 kgs	Flush	1340	490	1337	5.7	605	585	
(800 lbs)	Flush	1340	276	777	8.7			
Tablecloths	Break	420	1028	8465	12.9			X
	Suds	420	824	5984	12.6			
	Rinse 1	1340	720	2684	12.2			
	High Suds	670	418	2379	12.1			X
	Bleach	420	436	2942	10.7			X
	Rinse 2	1340	176	1354	10.4			
	Rinse 3	1340	116	820	10.1			
	Rinse 4	1340	82	553	9.9			
	Rinse 5	1340	99	450	9.7			
	Sour	250	155	1041	4.9	240	210	X
kgs/100 kgs Laundered			0.9	4.9	--	--	--	

TABLE C-3, CONTINUED

LINEN LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MARCH 16, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	BOD (mg/1)	Sus. Solids (mg/1)	Soluble TOC (mg/1)	Supplies Added
364 kgs (800 lbs) Kitchen Towels	Flush	1340	1450	3917	5.1		2410	300	
	Flush	1340	700	1977	7.9				
	Break	420	5050	18,075	12.6				X
	Suds	420	2450	9626	12.3				
	Rinse 1[1]	1340	820	3679	11.9				
	High Suds	670	660	2527	11.5				X
	Bleach	568e	510	3530	8.4				X
	Rinse 2	1340	190	1314	8.9	143			
	Rinse 3	1340	104	604	9.2				
	Rinse 4	1340	73	514	8.7				
	Rinse 5	1340	78	436	8.9				
	Sour	250	148	847	4.5	125		235	X
kgs/100 kgs Laundered			2.3	8.9	--	--	--		

[1] Alkalinity - 1110 mg/1 as $CaCO_3$
e = estimated

TABLE C-3, CONTINUED

LINEN LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MAY 19, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Suspended Solids (mg/1)	Supplies Added
136 kgs (300 lbs) Continuous Towels	Flush	644	107	435	6.85		
	Flush	644	151	434	8.1		
	Suds	242	1245	5250	12.1	112	X
	Carryover	242	913	3912	12.05		
	Suds	242	1205	4474	11.85		X
	Rinse 1	644	615	2580	11.55		
	Bleach	242	716	2999	11.35		X
	Rinse 2	644	327	1569	10.95		
	Rinse 3	644	218	1027	10.6		
	Rinse 4	644	214	935	10.55		
	Rinse 5	644	161	824	10.35		
	Sour	242	84	1228	4.85		X
kgs/100 kgs Laundered			1.6	6.8	--	--	

TABLE C-3, CONTINUED

LINEN LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MAY 19, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Supplies Added
304 kgs (800 lbs) Towels	Flush	1340	2520	9954	4.95	
	Flush	1340	1100	3297	5.1	
	Suds	420	3800$_e$	7000$_e$	--	X
	Rinse 1	1340	1240	4360	12.0	
	High Suds	420	1260	3387	11.85	
	Bleach	420	685	2444	10.4	
	Rinse 2	1340	436	1465	10.6	
	Rinse 3	1340	263	833	10.1	
	Rinse 4	1340	172	521	9.25	
	Rinse 5	1340	176	446	9.45	
	Sour	420	78	666	4.5	X
kgs/100 kgs Laundered			2.8	9.3		

e = estimated

TABLE C-3, CONTINUED

LINEN LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MAY 19, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	(units)	Sus. Solids (mg/1)	Supplies Added
136 kgs (300 lbs) Tablecloths	Flush	644	445	1034	5.85		
	Flush	644	435	865	6.4		
	Suds	242	2555	9548	12.3	330	X
	Carryover	242	1550	6341	12.35		
	Suds	242	2012	6638	12.0		X
	Rinse 1	644	740	2600	11.8		
	Bleach	242	952	2726	11.9		X
	Rinse 2	644	329	1276	11.25		
	Rinse 3	644	268	668	10.7		
	Rinse 4	644	150	483	10.1		
	Rinse 5	644	101	374	9.9		
	Sour	242	54	801	4.5		X
kgs/100 kgs Laundered			2.4	8.1	--	--	

TABLE C-3, CONTINUED

LINEN LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MAY 19, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/1)	Total Solids (mg/1)	pH (units)	Supplies Added
364 kgs	Flush	1340	320	748	6.5	
(800 lbs)	Flush	1340	250	548	6.7	
Tablecloths	Flush*	1340	248	578	7.0	
	Suds	420	856	5473	12.25	X
	Rinse 1	1340	300	1581	12.1	
	Suds	—	—	—	—	
	Bleach	420	227	943	10.2	X
	Rinse 2	1340	147	628	9.8	
	Rinse 3	1340	64	440	9.2	
	Rinse 4	1340	63	290	9.0	
	Rinse 5	1340	56	300	8.95	
	Sour	420	83	719	4.45	X
kgs/100 kgs laundered			0.7	3.0	—	

* Should have been a break.

TABLE C-3, CONTINUED

LINEN LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MAY 20, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/l)	Total Solids (mg/l)	pH (units)	Supplies Added
364 kgs	Flush	1340	175	175	8.1	
(800 lbs)	Flush	1340	--	--	8.95	
Napkins	Suds	420	375	7097	12.7	X
	Rinse 1	1340	580	4774	12.6	
	Suds	420	329	2404	12.2	
	Break	420	211	1231	10.8	X
	Rinse 2	1340	223	772	10.15	
	Rinse 3	1340	320	742	10.1	
	Rinse 4	1340	192	487	10.55	
	Rinse 5	1340	145	516	8.65	
	Sour	420	229	773	4.3	X
kgs/100 kgs Laundered			0.8	4.5		

TABLE C-3 CONTINUED

LINEN LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MAY 20, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/l)	Total Solids (mg/l)	pH (units)	Sus. Solids (mg/l)	Supplies Added
136 kgs	Flush	644	820	1451	8.8		
(300 lbs)	Suds	242	2232	12,214	12.75	385	X
Tablecloths	Carryover	242	710	6066	12.5		
	Suds	242	--	--			
	Rinse 1	644	--	--			
	Bleach	242	290	1113	11.15		
	Rinse 2	644	89	410	10.1		
	Rinse 3	644	50	211	9.5		
	Rinse 4	644	36	426	9.25		
	Rinse 5	644	23	163	8.75		
	Sour	644	32	605	4.2	440	X
kgs/100 kgs Laundered			1.59	6.20			

e = estimated

TABLE C-3, CONTINUED

LINEN LAUNDRY SURVEY WASH WHEEL
DISCHARGE DATA
MAY 20, 1971

Article Laundered	Operation	Water Volume (liters)	TOC (mg/l)	Total Solids (mg/l)	pH (units)	Suspended Solids (mg/l)	Supplies Added
364 kgs	Flush	1340	1296	3211	7.5	1000e	
(800 lbs)	Flush	1340	480	1083	8.6	360	
Kitchen	Break	--	--	--	--	--	
Towels	Suds	420	3030	8004	12.6	1895	X
	Rinse 1	1340	448	3898	12.3	380	
	High Suds	420	1140	2944	12.05	745	
	Bleach	420	600	2115	10.8	430	
	Rinse 2	1340	164	714	10.1	110	
	Rinse 3	1340	92	426	9.7	102	
	Rinse 4	1340	44	334	9.4	43	
	Rinse 5	1340	156	343	9.0	85	
	Sour	420	10	337	4.6	9	X
kgs/100 kgs Laundered			1.4	5.0		1.1	

e = estimated

TABLE C-4

INDUSTRIAL LAUNDRY WASTEWATER TREATMENT SYSTEM

OPERATING CONDITIONS

Parameter	23 Jan.	24 Jan.	Run-1 25 Jan.	Run-2 25 Jan.	26 Jan.
$CaCl_2$ dosage - mg/l	4886	2264	5766	5804	2804
A-23 dosage - mg/l	1.93	1.99	2.40	2.37	3.69
Avg. Raw Flow - lpm	416	511	530	545	606
Recycle - %	76.9	74.0	77.1	75.0	62.5
Length of run - hours	4.926	5.740	1.783	1.660	1.689
Flotation Mass Loading kg/day/sq m	49	39	127	131	109
Average Filtrate Flow - lpm	21	--	13	44	28
Print wipers - % of industrial load	20.0	19.4	15.6	15.6	14.8
% of Time Filter Blinded	53	35	8	0	90
Vacuum Filtration Time - hours	4.12	4.87	1.32	1.70	1.0
Sludge Volume - l/1000 l raw waste					
DE Body Feed - mg DE/mg SS	0.73	0.69	-	0.57	0
DE Pressure Buildup kg/sq cm/hr	4.0	3.6	-	8.3	0
Acid Dosage - mg/l	0	213	254	232	-
Overflow Rate lpm/sq m	74	90	94	96	99

TABLE C-4 CONTINUED

INDUSTRIAL LAUNDRY WASTEWATER TREATMENT SYSTEM

OPERATING CONDITIONS

Parameter	Run 1 30 Jan.	Run 2 30 Jan.	31 Jan.	9 Aug.	20 Oct.
$CaCl_2$ Dosage - mg/l	3016	3372	3656	1660	2040
A-23 Dosage - mg/l	2.88	1.95	1.52	1.30	0.50
Avg. Raw Flow - lpm	606	484	435	643	795
Recycle %	62.5	78.1	87.0	59.0	47.6
Length of Run - Hours	1.509	2.920	2.540	3.12	4.07
Flotation Mass Loading kg/day/sq m	212	159	332	290	-
Average Filtrate Flow., lpm	-	19	12	-	48
Print Wipers - % of Industrial Load	16.7	16.7	0	-	-
% of Time Filter Blinded	-	0	0	-	0
Vacuum Filtration Time - hrs.	-	2.23	1.89	0	3.5
Sludge Volume - 1/1000 l raw waste	-	20	20	-	5.7
DE Body Feed - mg DE/mg SS	0	0.81	0	2.0	-
DE Pressure Buildup, kg/sq m/hr	0	0.2	0	0.5	7.2
Acid Dosage - mg/l	430	0	0	-	-
Overflow Rate, lpm/sq m	99	87	82	103	118

TABLE C-5

VACUUM FILTRATION OPERATING

CONDITIONS FOR INDUSTRIAL LAUNDRY WASTEWATER TREATMENT

Date	Time	Scum* Solids (Percent)	Cycle Time (Minutes)	Pickup Time (Minutes)	Vacuum Level (cm Hg)	Cake Solids (Percent)	Solids Loading (kg/sq m)	Yield (kg/sq m/hr)	Scum Volatile Solids-%	Scum Suspended Solids-%
10/20/72	8:12 AM	5.48	5.5	1.51	61	45.97	1.55	16.9		
	9:00	5.26	5.5	1.47	61	53.53	1.23	13.3		
	10:35	14.29								
1/23/73		5.28								
	11:30AM		4	0.82	64	27.12	1.77	26.5	3.48	2.22
	12:03		4	0.82	69	26.80	2.44	36.6		
	1:52PM		5.5	1.13	61	40.71	1.06	11.6		
	2:36		5.5	1.13	61	31.51	2.17	23.7		
	3:12		5.5	1.13	61	25.98	3.00	32.7		
1/24/73		3.47								
	7:50AM		5.0	1.30	38-51	15.38	1.78	21.3	2.12	2.92
	8:02		5.0	1.30	38-51	19.18	1.29	15.5		
	10:05		5.5	-	-	32.75	1.05	11.4		
	10:45		5.5	-	-	27.56	1.86	20.2		
	11:30		5.5	-	-	27.10	2.49	27.1		
	11:59		5.5	-	-	28.27	2.24	24.5		
1/25/73		7.29								
	8:40AM		5.5	-	-	30.19	2.17	23.7	5.23	6.34
	8:51		5.5	-	-	29.79	1.86	20.3		
	11:22		5.0	-	69	29.80	4.90	58.9		
	11:55		5.0	-	69	26.48	3.10	37.2		
	12:22PM		5.0	-	66	30.00	1.91	22.9		
	-		5.0	-	66	37.60	4.62	55.5		

TABLE C-5 CONTINUED

VACUUM FILTRATION OPERATING

CONDITIONS FOR INDUSTRIAL LAUNDRY WASTEWATER TREATMENT

Date	Time	Scum* Solids (Percent)	Cycle Time (Minutes)	Pickup Time (Minutes)	Vacuum Level (cm Hg)	Cake Solids (Percent)	Solids Loading (kg/sq m)	Yield kg/sq m/hr	Scum Volatile Solids-%	Scum Suspended Solids-%
1/26/73		2.31							2.12	2.27
1/30/73	1:20PM	2.98	5.5	-	43-64	33.83	1.32	14.5	1.58	2.66
	2:10		5.5	-	-	23.77	1.95	21.2		
	2:50		5.5	-	-	16.30	2.81	30.6		
	3:15		5.5	0.79	18	15.44	1.08	11.8		
	3:42		5.5	0.79	18	14.32	1.51	11.9		
1/31/73		3.24							1.88	2.99
	1:20PM		5.5	-	-	31.21	1.51	16.5		
	2:21		5.5	-	-	25.78	1.91	20.8		
	2:25		5.5	-	-	24.56	2.31	25.2		

* Composite for Day

TABLE C-6

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

9 AUGUST 1972

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		11.85	11.5	-	11.45	-		
BOD, mg/l								
TOC, mg/l		6300	440	93.0	320	94.7		
Total Solids, mg/l		8649	5694	34.2	5609	35.1		
Vol. Total Solids, mg/l								
Suspended Solids, mg/l		4950	108	97.8	9	99.8		
Vol. Sus. Solids, mg/l								
Grease, mg/l		2805	146	94.8	17	99.4		
Alkalinity to pH 8.3*								
Alkalinity to pH 3.7*								

* mg/l as $CaCO_3$

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/l								
Mg, mg/l								
Cu, mg/l		9.30	0.69	92.6	0.56	94.0		
Pb, mg/l		35.80	0.35	99.0	0.10	99.7		
Hg, µg/l		1.20	<0.50	58.3	<0.50	58.3		
Cd, mg/l		0.60	0.03	95.0	0.03	95.0		
Zn, mg/l		8.88	0.35	96.1	0.18	98.0		
Cr, mg/l		3.60	3.25	9.70	3.86	0		
Fe, mg/l		126	2.40	98.1	2.40	98.1		
Ni, mg/l		1.00	0.30	70.0	0.20	80.0		
Si, mg/l		230	7	98.7	8	96.5		

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

20 OCTOBER 1972

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		11.7	10.9	-	10.65	-		
BOD, mg/l								
TOC, mg/l		4200	1740	58.5	123	92.3		
Total Solids, mg/l		6662	6670	0	2876	56.8		
Vol. Total Solids, mg/l								
Suspended Solids, mg/l		3775	2914	22.8	48	98.7		
Vol. Sus. Solids, mg/l								
Grease, mg/l		3756	1663	55.7	16	99.6		
Alkalinity to pH 8.3*								
Alkalinity to pH 3.7*								

* mg/l as $CaCO_3$

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/l								
Mg, mg/l								
Cu, mg/l		6.10			0.20	96.7		
Pb, mg/l		16.50			0.20	98.8		
Hg, µg/l								
Cd, mg/l		0.45			0.10	77.8		
Zn, mg/l		6.80			0.06	99.1		
Cr, mg/l		2.25			0.26	88.4		
Fe, mg/l		67			0.20	99.7		
Ni, mg/l		1.00			1.00	0		
Si, mg/l		252	13	94.8	33	86.9		

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

23 JANUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		10.7	10.4	--	10.9	-		
BOD, mg/l		710	537	24.37	353	50.28		
TOC, mg/l		950	670	29.47	380	60.00		
Total Solids, mg/l		5561	5333	4.10	5307	4.57	52798	
Vol. Total Solids, mg/l		1184	785	33.70	663	44.00	34884	
Suspended Solids, mg/l		814	279	65.72	174	78.62	22230	2981
Vol. Sus. Solids, mg/l		566	216	61.84	152	73.14		2664
Grease, mg/l		403	260	35.48	266	34.00		
Alkalinity to pH 8.3*		190	110	--	160	-		
Alkalinity to pH 3.7*		420	270	--	320	-		

* mg/l as $CaCo_3$

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/l		840	805		684	18.57		
Mg, mg/l		2.20	1.00	54.55	0.20	90.91		
Cu, mg/l		1.50	0.30	80.00	0.40	73.33		
Pb, mg/l		4.50	3.30	26.67	2.20	51.11		
Hg, µg/l		3.50	1.20	65.71	0.50	85.71		
Cd, mg/l		0.35	0.30	14.29	0.28	20.00		
Zn, mg/l		1.60	0.23	85.63	<0.02	>98.75		
Cr, mg/l		1.15	1.43	0	1.66	0		
Fe, mg/l		3.50	0.80	77.14	0.40	88.57		
Ni, mg/l		2.50	2.00	20.00	1.80	28.00		
Si, mg/l		79	77	2.53	28	64.56		

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

24 JANUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		10.8	8.7	-	8.6	-		
BOD, mg/l		647	708	0	334	48.34		
TOC, mg/l		1020	1200	0	470	53.92		
Total Solids, mg/l		4884	4058	16.91	3937	19.39	34721	
Vol. Total Solids, mg/l		1190	1037	12.86	644	45.88	21150	
Suspended Solids, mg/l		649	404	37.75	129	80.12	29240	1686
Vol. Sus. Solids, mg/l		464	370	20.26	116	75.00		1540
Grease, mg/l		511	605	0	142	72.21		
Alkalinity to pH 8.3*		190	20	-	10	-		
Alkalinity to pH 3.7*		380	150	-	140	-		

* mg/l as $CaCO_3$

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/l		580	300	48.28	384	33.79		
Mg, mg/l		1.60	0.60	62.50	0.30	81.25		
Cu, mg/l		0.20	0.40	0	0.30	0		
Pb, mg/l		3.00	2.50	16.67	1.80	40.00		
Hg, µg/l		1.20	1.20	0	0.80	33.33		
Cd, mg/l		0.10	0.40	0	0.12	0		
Zn, mg/l		0.55	0.35	36.36	0.06	89.09		
Cr, mg/l		2.20	2.43	0	2.96	0		
Fe, mg/l		6.50	2.50	61.54	1.00	84.62		
Ni, mg/l		2.00	1.30	35.00	1.20	40.00		
Si, mg/l		47	107	0	86	0		

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

25 JANUARY 1973

RUN 1

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	10.9		5.0	-			10.9	
BOD, mg/1	1314		820	37.60				
TOC, mg/1	2650		960	63.43				
Total Solids, mg/1	7243		4987	31.15			72933	
Vol. Total Solids, mg/1	2749		991	63.95			52327	
Suspended Solids, mg/1	3509		553	84.24			63430	2448
Vol. Sus. Solids, mg/1	2247		524	76.59				2280
Grease, mg/1	1623		387	74.14				
Alkalinity to pH 8.3*	360		0	-				
Alkalinity to pH 3.7*	950		80	-				

* mg/1 as $CaCO_3$

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/l	830		630	24.10				
Mg, mg/l	14.00		0.60	95.71				
Cu, mg/l	3.40		0.50	85.29				
Pb, mg/l	14.50		3.00	79.31				
Hg, mg/l	--		1.20	--				
Cd, mg/l	0.12		0.35	0				
Zn, mg/l	4.90		0.60	87.76				
Cr, mg/l	3.55		0.95	73.24				
Fe, mg/l	44.50		1.50	96.63				
Ni, mg/l	2.00		1.00	50.00				
Si, mg/l	21		68	0				

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

25 JANUARY 1973

RUN 2

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	10.7	9.8	9.25	-	8.65	-		
BOD, mg/1			1167	-	319	72.66		
TOC, mg/1	1480	2340	2080	11.11	430	70.95		
Total Solids, mg/1	5728		5276	7.89	4097	28.47		
Vol. Total Solids, mg/1	1497		1357	9.35	720	51.90		
Suspended Solids, mg/1	1655	3034	614	62.90	142	91.42		2894
Vol. Sus. Solids, mg/1	1020		498	51.18	86	91.57		2816
Grease, mg/1	966		953	1.35	123	87.27		
Alkalinity to pH 8.3*	90	340	45		10			
Alkalinity to pH 3.7*	490	940	210		170			

* mg/1 as $CaCO_3$

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/1	590		465	21.19	440	25.42		
Mg, mg/1	5.80		0.50	91.38	0.40	93.10		
Cu, mg/1	2.50		0.90	64.00	0.70	72.00		
Pb, mg/1	8.50		2.30	72.94	2.00	76.47		
Hg, ug/1	--		--	--	1.20	--		
Cd, mg/1	<0.05		0.20	0	0.35	0		
Zn, mg/1	2.15		0.38	82.33	0.10	95.35		
Cr, mg/1	3.00		1.93	35.67	1.95	35.00		
Fe, mg/1	17.00		1.30	92.35	0.50	97.06		
Ni, mg/1	1.00		1.00	0	1.00	0		
Si, mg/1	21		84	0	81	0		

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

26 JANUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		10.1	10.85	-				
BOD, mg/l		692	725	0				
TOC, mg/l		1380	1110	19.57				
Total Solids, mg/l		4856	3953	18.60			26434	
Vol. Total Solids, mg/l		1422	1129	20.60			15283	
Suspended Solids, mg/l		1810	408	77.46			22700	2121
Vol. Sus. Solids, mg/l		985	320	67.51				2095
Grease, mg/l		725	763	0				
Alkalinity to pH 8.3*		120	265	-				
Alkalinity to pH 3.7*		600	450	-				

* mg/l as $CaCO_3$

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filter
Ca, mg/l		400	220	45.00				
Mg, mg/l		5.15	0.40	92.23				
Cu, mg/l		1.50	0.90	40.00				
Pb, mg/l		6.00	2.50	58.33				
Hg, µg/l		--	--	--				
Cd, mg/l		0.00	0.25	0				
Zn, mg/l		1.65	<0.02	98.79				
Cr, mg/l		1.00	1.40	0				
Fe, mg/l		16.00	1.00	93.75				
Ni, mg/l		1.00	1.00	0				
Si, mg/l		60	128	0				

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

30 JANUARY 1973

RUN 1

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		10.45	10.45		9.80			
BOD, mg/1								
TOC, mg/1		1620	370	77.2	450	72.2		
Total Solids, mg/1		6246	3452	44.7	3130	49.9		
Vol. Total Solids, mg/1								
Suspended Solids, mg/1								
Vol. Sus. Solids, mg/1								
Grease, mg/1		1160	154	86.0	19	98.4		
Alkalinity to pH 8.3*		390	163		150			
Alkalinity to pH 3.7*		1240	185		208			

* mg/1 as $CaCO_3$

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

30 JANUARY 1973 - RUN 2

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	10.2		10.1	-	10.6	-		
BOD, mg/l	943		313	66.81	1574†	-		
TOC, mg/l	1700		460	72.94	1820†	-		
Total Solids, mg/l	6061		3610	40.44	3555	41.35	29849	
Vol. Total Solids, mg/l	1846		635	65.60	711	61.48	15779	
Suspended Solids, mg/l	2625		236	91.01	20	99.24	26640	1262
Vol. Sus. Solids. mg/l	1425		161	88.70	13	99.09		1219
Grease, mg/l	1163		185	84.09	82	92.95		
Alkalinity to pH 8.3*	315		90		115			
Alkalinity to pH 3.7*	930		220		220			

* mg/l as $CaCO_3$
† Organic Sample Contamination

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

30 JANUARY 1973 - RUN 2

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System. Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/l	710		385		360			
Mg, mg/l	8.5		0.1		0.08			
Cu, mg/l	2.8		0.5	82.1	0.40	85.7		
Pb, mg/l	9.5		0.6	93.7	0.50	94.7		
Hg, μg/l	7.0		0.6	91.3	0.60	91.3		
Cd, mg/l	<0.05		0.01	80	0.01	80		
Zn, mg/l	3.4		0.17	95	0.02	99.4		
Cr, mg/l	1.5		1.2	20	1.3	20		
Fe, mg/l	25		0.8	96.8	0.7	97.2		
Ni, mg/l	1.0		0.3	70	0.3	70		
Si, mg/l								

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

31 JANUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	11.20	10.8	10.7	-				
BOD, mg/1		677	566	17.87				
TOC, mg/1	2660	4200	1040	75.59				
Total Solids, mg/1		8538	3896	54.37			32403	
Vol. Total Solids, mg/1		3747	1855	50.49			18796	
Suspended Solids, mg/1	3303	5495	550	89.99			29930	
Vol. Sus. Solids, mg/1		3495	460	86.84				
Grease, mg/1	2265	2979	-	-				
Alkalinity to pH 8.3*	540	530	130	0				
Alkalinity to pH 3.7*	1080	1380	350	-				

* mg/1 as $CaCO_3$

TABLE C-6, CONTINUED

LABORATORY ANALYSIS

FOR INDUSTRIAL WASTEWATER TREATMENT

31 JANUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/1		300	270	10.00				
Mg, mg/1		21	0.90	95.71				
Cu, mg/1		6.20	1.50	75.81				
Pb, mg/1		20.50	0.80	96.10				
Hg, μg/1		--	--	--				
Cd, mg/1		0.20	0.02	90.00				
Zn, mg/1		6.80	0.44	93.53				
Cr, mg/1		3.20	1.60	50.00				
Fe, mg/1		72	1.00	98.61				
Ni, mg/1		1.00	0.60	40.00				
Si, mg/1		--	--	--				

TABLE C-7

UNIFORM WASTE TREATMENT SYSTEM

OPERATING CONDITIONS

Parameter	2 Feb.	6 Feb.	7 Feb.*	8 Feb.	9 Feb.	Run 1 13 Feb.	Run 2 13 Feb.
$CaCl_2$ Dosage - mg/l	2132	2316	3193	3506	6991	1578	2454
A-23 Dosage - mg/l	2.73		3.43	0.27	2.37	1.98	2.88
Avg. Raw Flow - lpm	500	397	303	288	541	541	416
Recycle - %	82.1	103.2	135.6	142.5	75.4	75.4	98.2
Length of run - hours	3.05	2.77	1.47	0.78	1.71	1.35	2.42
Total wastewater volume treated - cu m	91.4	66.1	26.7	13.5	55.5	43.9	60.5
Filtrate Flow - lpm	53	51	-	76	58	56	37
% Filter Blinded	0	0	0	0	0	0	10%
Sludge Volume - 1/1000 l raw waste	14.3 est.	16.2	41.7	27.1	13.5	11.4	10.7
Filter Time - hours	-	1.12	1.41	0.45	0.99	0.85	1.96
DE Body Feed - mg DE/mg SS							3.0
DE Pressure Buildup, kg/sq cm/hr							0.5
Flotation Mass loading, kg/day/sq m	128	18	-	18	126		53
Overflow Rate, lpm/sq m	91	84	72	70	95	95	83

* Print wiper contamination

TABLE C-8

VACUUM FILTRATION OPERATING

CONDITIONS FOR UNIFORM LAUNDRY WASTEWATER TREATMENT

Date	Time	Scum* Solids (Percent)	Cycle Time (Minutes)	Pickup Time (Minutes)	Vacuum Level (in Hg)	Cake Solids (Percent)	Solids Loading (kg/sq m)	Yield (kg/sq m/hr)	Scum* Volatile Solids-%	Scum* Suspended Solids-%
2/2/73	12:27 pm	1.52	5.5	0.80	-	19.72	1.18	12.8	0.482	1.23
	12:31		5.5	0.85	-	19.75	1.33	14.5		
2/6/73	12:10 pm	2.15	5.5	1.62	-	14.20	1.04	11.3	0.567	1.61
	12:45		5.5	-	-	10.66	1.41	15.4		
	1:30		5.5	-	-	11.01	0.90	9.8		
2/7/73	2:11 pm	2.63	5.5	1.62	51	14.58	0.89	9.7	1.104	2.16
	2:27		5.5	1.03	51	13.13	1.30	14.2		
	3:10		5.5	1.40	38-56	15.20	1.10	12.0		
2/8/73	2:35 pm	3.53	5.5	-	-	16.70	1.32	14.4	1.660	2.99
2/9/73	12:35 pm	2.49	5.5	1.46	30-38	13.69	1.09	11.9	0.736	1.88
	1:25		5.5	1.46	-	15.81	1.08	11.8		
2/13/73	11:30-1	1.19	5.5	1.28	28-41	14.60	1.03	11.3	0.249	0.52
	11:55-1		5.5	1.62	25-51	17.17	0.78	8.5		
	3:18-2		5.5	1.28	-	18.79	0.60	6.6		

* Daily Composite Sample

TABLE C-9

LABORATORY ANALYSIS

FOR UNIFORM WASTEWATER TREATMENT

2 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	10.45		10.9	--				
BOD, mg/1	--		--	--				
TOC, mg/1	600		570	5				
Total Solids, mg/1	4266		3531	17.23			151588	
Vol. Total Solids, mg/1	1246		769	38.28			4822	
Suspended Solids, mg/1	1765		185	89.6			12310	150
Vol. Sus. Solids, mg/1	705		161	77.16				199
Grease, mg/1	180		224	0			2326	
Alkalinity to pH 8.3*	545		275					
Alkalinity to pH 3.7*	1050		430					

* mg/1 as $CaCO_3$

TABLE C-9, CONTINUED

LABORATORY ANALYSIS

FOR UNIFORM WASTEWATER TREATMENT

6 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	11.2		9.0					
BOD, mg/1	192		234	0				
TOC, mg/1	460		460	0				
Total Solids, mg/1	2801		5550	0			21457	
Vol. Total Solids, mg/1	985		1064	0			5674	
Suspended Solids, mg/1	316		243	23.1			16060	204
Vol. Suspended Solids, mg/1	233		166	28.75				139
Grease, mg/1	173		177	0			2042	
Alkalinity to pH 8.3*	695		25					
Alkalinity to pH 3.7*	1045		195					

* mg/1 as $CaCO_3$

TABLE C-9, CONTINUED

LABORATORY ANALYSIS

FOR UNIFORM WASTEWATER TREATMENT

6 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/l	22		670					
Mg, mg/l	5.5		0.28	94.9				
Cu, mg/l	0.85		0.42	50.6				
Pb, mg/l	3.7		1.0	73.0				
Hg, µg/l	3.0		0.8	73.3				
Cd, mg/l	0.13		0.01	92.3				
Zn, mg/l	7.8		0.65	91.7				
Cr, mg/l	0.17		0.11	35.3				
Fe, mg/l	21		1.11	94.7				
Ni, mg/l	1.0		0.90	10.0				
Si, mg/l	232		42	81.9				

TABLE C-9, CONTINUED

LABORATORY ANALYSIS

FOR UNIFORM WASTEWATER TREATMENT

7 FEBRUARY 1973 †

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		12.4	--	--				
BOD, mg/1		--	--	--				
TOC, mg/1		3480	1700	51.2				
Total Solids, mg/1		7761	--	--			26303	
Vol. Total Solids, mg/1		--	--	--			11035	
Suspended Solids, mg/1		--	2265	--			21630	215
Vol. Sus. Solids, mg/1		--	--	--				163
Grease, mg/1		1888	750	60.27				
Alkalinity to pH 8.3*		--	--	--				
Alkalinity to pH 3.7*		--	--	--				

* mg/1 as $CaCO_3$

† Print wiper contamination

TABLE C-9, CONTINUED

LABORATORY ANALYSIS

FOR UNIFORM WASTEWATER TREATMENT

8 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	11.65		11.8	--				
BOD, mg/1	473		449	5.1				
TOC, mg/1	765		570	5.5				
Total Solids, mg/1	3775		5974	0			35332	
Vol. Total Solids, mg/1	1531		539	64.8			16624	
Suspended Solids, mg/1	437		130	70.3			29890	150
Vol. Sus. Solids, mg/1	299		60	79.9				112
Grease, mg/1	369		242	34.4			10134	
Alkalinity to pH 8.3*	945		735					
Alkalinity to pH 3.7*	1365		890					
Ca, mg/1	--	1180						

* mg/1 as $CaCO_3$

TABLE C-9, CONTINUED

LABORATORY ANALYSIS

FOR UNIFORM WASTEWATER TREATMENT

9 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	9.85		10.35	--				
BOD, mg/1	295		227	23.1				
TOC, mg/1	400		335	16.3				
Total Solids, mg/1	6967		6547	6.0			24935	
Vol. Total Solids, mg/1	1275		1108	13.1			7356	
Suspended Solids, mg/1	1610		67	95.8			18800	95
Vol. Sus. Solids, mg/1	528		64	87.9				78
Grease, mg/1	122		107	12.3				
Alkalinity to pH 8.3*	255		145					
Alkalinity to pH 3.7*	820		245					

* mg/1 as $CaCO_3$

TABLE C-9, CONTINUED

LABORATORY ANALYSIS

FOR UNIFORM WASTEWATER TREATMENT

13 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	10.9		9.70	--	9.65	--		
BOD, mg/1	228		240	0	124	45.6		
TOC, mg/1	540		435	19.4	225	58.3		
Total Solids, mg/1	3268		6900	0	4443	0	11925	
Vol. Total Solids, mg/1	1011		759	24.9	757	25.1	2485	
Suspended Solids, mg/1	885		218	75.4	30	96.6	5220	113
Vol. Sus. Solids, mg/1	313		120	61.7	27	91.4		69
Grease, mg/1	324		198	38.9	26	92.0	834	
Alkalinity to pH 8.3*	675		115		110			
Alkalinity to pH 3.7*	1100		250		185			

* mg/1 as $CaCO_3$

TABLE C-9, CONTINUED

LABORATORY ANALYSIS

FOR UNIFORM WASTEWATER TREATMENT

13 FEBRUARY 1973

Analysis	Raw Waste to Pit	Raw Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/l	163		1675	0	860	0		
Mg, mg/l	9.80		1.20	87.8	1.23	87.4		
Cu, mg/l	7.90		0.42	94.7	<0.10	>98.7		
Pb, mg/l	6.50		1.60	75.4	0.90	86.2		
Hg, µg/l	4.30		0.60	86.0	0.60	86.0		
Cd, mg/l	0.15		0.02	86.7	0.02	86.7		
Zn, mg/l	6.20		0.43	93.1	0.03	99.5		
Cr, mg/l	1.60		0.17	89.4	0.11	93.1		
Fe, mg/l	72.00		1.70	97.6	0.76	98.9		
Ni, mg/l	1.00		1.10	0	0.70	30.0		
Si, mg/l	216		52	75.9	63	70.8		

TABLE C-10

LINEN LAUNDRY WASTE TREATMENT SYSTEM

OPERATING CONDITIONS

Parameter	Run 1 20 Feb.	Run 2 20 Feb.	21 Feb.	22 Feb.	23 Feb.	27 Feb.	28 Feb.
$CaCl_2$ dosage - mg/1	1728	1375	2044	2195	1464	1956	2604
A-23 dosage - mg/1	2.30	2.67	1.94	1.37	1.54	1.58	1.70
Avg. Raw Flow - lpm	459	484	471	473	492	517	503
Recycle - %	89.0	84.4	86.7	86.4	83.1	79.2	79.07
Time of Run - hours	2.40	1.84	2.17	3.14	4.22	1.695	2.065
Solids Loading - kgs/day/sq m	15	8	7	19	16	49	60
Total wastewater volume treated -cu m	66.1	53.5	61.4	90.9	121.3	52.5	62.3
Filtrate flow - lpm	70	70	84	120	71	87	81
Sludge volume - 1/1000 1 raw waste	18.3	6.2	3.0	--	4.6	3.0	7.0
Filter time - hours	0.89	0.68	0.62	0.49	1.41	0.46	0.70
Wash load - kgs linen	1909	1909	2909	3273	3455	4000	4182
DE Pressure Buildup, kg/sq cm/hr	--	--	--	--	--	0	0.09
Overflow Rate, lpm/sq m	87	90	88	89	90	93	90

TABLE C-10, CONTINUED

LINEN LAUNDRY WASTE TREATMENT SYSTEM

OPERATING CONDITIONS

Parameter	Run 1 1 Mar.	Run 2 1 Mar.	14 Mar.	Run 1 15 Mar.	Run2 15 Mar.	16 Mar.	20 Mar.
$CaCl_2$ dosage - mg/1	2821	2571	1784	1888	1295	787	1017
A-23 Dosage - mg/1	1.68	1.65	1.68	1.58	2.35	0.78	2.18
Avg. Raw Flow - lpm	517	492	488	498	495	467	447
Recycle %	79.0	83.1	83.8	82.0	82.6	87.5	91.5
Time of Run - hours	2.61	1.94	3.19	2.00	2.36	2.90	3.15
Solids loading, kgs/day/sq m	14	5	19	62	63	50	70
Total wastewater volume treated- cu m	81.0	57.3	93.4	59.8	70.1	81.3	84.5
Filtrate Flow - lpm	90	95	96	78	86	92	67
Sludge volume- 1/1000 1 raw waste	4.4	4.6	1.4	1.5	3.9	3.9	2.8
Filter time - hours	0.79	0.53	0.215	0.15	0.74	0.67	0.31
Wash load - kgs linen	2294	1706	4182	1585	1870	4545	4364
DE pressure buildup, kg/sq cm/hr	--	0.20	<0.07	--	0.07	0.90	
Overflow Rate, lpm/sq m	90	90	90	91	91	88	86

TABLE C-10, CONTINUED

LINEN LAUNDRY WASTE TREATMENT SYSTEM

OPERATING CONDITIONS

Parameter	21 Mar.	22 Mar.	23 Mar.	28 Mar.	29 Mar.	19 April
$CaCl_2$ dosage - mg/1	1526	1419	1455	2385	2385	1570
A-23 Dosage - mg/1	1.54	1.58	1.39	1.28	1.91	0.83
Avg. Raw Flow - lpm	463	416	509	448	310	497
Recycle - %	88.2	98.4	80.3	91.27	132.00	82.3
Time of Run - hours	2.19	3.24	1.71	4.43	2.45	1.83
Solids loading, kgs/day/sq m	299	92	76	51	25	159
Total wastewater volume treated- cu m	60.7	80.8	51.9	119.0	45.5	54.5
Filtrate flow - lpm	92	76	92	130	98	
Sludge volume- 1/1000 1 raw waste	22.1	20.2	6.4	1.7		
Filter time - hours	1.1	1.28	0.34	0.87	0.47	0.23
Wash load - kgs linens	2909	2909	3273	3636	3091	4364
DE pressure Buildup -kgs/sq cm/hr	--	--	0.05	0.16	0.26	1.52
Overflow Rate, lpm/sq m	88	83	92	86	72	91

TABLE C-11

VACUUM FILTRATION OPERATING

CONDITIONS FOR LINEN LAUNDRY WASTEWATER TREATMENT

Date	Time	Scum Solids (percent)	Cycle Time (minutes)	Pickup Time (minutes)	Vacuum Level (cm Hg)	Cake Solids (percent)	Solids Loading (kg/sq m)	Yield (kg/sq m/hr)	Scum Volatile Solids-%	Scum Suspended Solids-%
2/20/73	11:20 am	1.251	5.5	0.874	43	27.02	2.97	32.4	0.4917	0.8820
	12:30 pm		5.5	0.550	30-38	20.98	2.05	22.4		
2/20/73	1:05 pm	1.322	5.5	1.045	43	26.55	1.23	13.4	0.4988	1.0175
	1:45		5.5	0.550	43	12.56	0.61	6.7		
2/21/73	12:59 pm	0.5514	5.5	0.687	43	15.03	0.35	3.8	0.2074	0.2230
	2:00		5.5	--	--	19.81	0.68	7.5		
2/22/73		0.7022	--	--	--	--	--	--	0.2682	0.3800
2/23/73	6:57 am	0.8643	5.5	--	--	29.06	0.60	6.5	0.3209	0.5915
	9:30		5.5	0.935	51-64	--	1.06	11.5		
	10:19		5.5	0.550	46	--	0.84	9.2		
	10:50		5.5	0.825	51-64	23.77	1.18	12.9		
	1:28 pm		5.5	--	--	22.46	1.11	12.1		
2/27/73	1:00 pm	1.0489	5.5	0.550	38	27.12	0.85	9.3	0.4006	0.5240
	1:45		5.5	0.852	38	31.27	1.09	11.9		
2/28/73	11:03 am	1.4965	5.5	1.265	--	15.20	1.64	17.7	0.5495	0.9890
	11:10		5.5	0.660	--	20.00	0.91	9.9		
	12:00 pm		5.5	0.660	--	21.80	0.94	10.3		

3/29/73		0.6176	5.5	--	--	--	--	--	0.1070	--
4/19/73		4.760	5.5	--	--	--	--	--	2.3900	4.1200
3/1/73	7:35 am	0.9856	5.5	0.880	--	24.63	0.76	8.3	0.2898	0.5310
	8:06		5.5	0.907	51	22.76	0.72	7.8		
	8:49		5.5	0.907	51	22.37	1.44	15.8		
	9:35		5.5	0.660	--	23.69	1.14	12.4		
3/1/73	12:00 pm	1.3069	5.5	0.715	51	26.76	1.53	16.7	0.4322	0.8090
	2:50		5.5	0.715	38	26.15	1.03	11.2		
3/14/73	11:45 am	1.7400	5.5	1.375	--	27.32	1.62	17.6	0.6660	1.2600
3/15/73	10:32 am	0.9300	5.5	--	--	24.26	1.39	15.2	0.3630	0.6130
	11:15		5.5	--	--	23.96	1.38	15.0		
3/15/73	12:35 pm	1.3800	5.5	--	--	23.25	0.85	9.3	0.5300	1.1600
	1:00		5.5	--	--	24.97	0.89	9.7		
3/16/73	10:35 am	1.1900	5.5	--	--	26.45	1.01	11.0	0.4100	1.0400
	11:15		5.5	--	--	22.78	1.23	13.5		
3/20/73	2:30 pm	3.9263	5.5	--	--	13.34	1.00	10.9	1.4472	1.1663
3/21/73	9:48 pm	1.3642	5.5	1.265	--	12.15	3.06	33.4	0.9690	1.0388
	10:03		5.5	0.715	--	13.91	0.96	10.5		
	10:51		5.5	0.660	--	15.44	0.89	9.8		
3/22/73	11:30 am	2.1827	5.5	--	--	16.55	1.65	18.0	2.1796	1.6288
	1:50 pm		5.5	--	--	13.98	2.15	23.4		
3/23/73	12:30 pm	1.9407	5.5	--	--	11.92	1.18	12.8	1.5522	1.4392
	1:00		5.5	--	--	11.56	1.53	16.6		
	2:15		5.5	--	--	13.86	0.86	9.4		
3/28/73		1.1200	5.5	--	--	25.28	0.65	7.1	0.3870	0.7510
			5.5	--	--	27.90	0.56	6.1		

TABLE C-12

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

20 FEBRUARY 1973

RUN 1

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	11.0		9.95	--				
BOD, mg/l	544**		118	78.31				
TOC, mg/l	430		113	73.72				
Total Solids, mg/l	1800		3277	0			12509	
Vol. Total Solids, mg/l	788		537	31.85			4917	
Suspended Solids, mg/l	230		63	72.61			8820	126
Vol. Sus. Solids, mg/l	219		34	84.47				69
Grease, mg/l	193	326	14	92.75				
Alkalinity to pH 3.3*	300		100					
Alkalinity to pH 3.7*	680		180					

* mg/l as $CaCO_3$
** measured as 6 day BOD, calculated 5 day BOD using K = 0.1

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

20 FEBRUARY 1973

RUN 2

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation % Removal	D.E. Effluent	System % Removal	Floated Scum	Vac. Filt. Filtrate
pH, units	11.52		980	--				
BOD, mg/1	150**		126	16.12				
TOC, mg/1	289		125	56.75				
Total Solids, mg/1	1601		3202	0			13221	
Volatile Total Solids, mg/1	537		489	8.94			4988	
Suspended Solids, mg/1	110		41	62.73			10175	87
Volatile Suspended Solids, mg/1	107		37	65.42				54
Grease, mg/1	65	219	32	80.6				
Alkalinity to pH 8.3*	620		110					
Alkalinity to pH 3.7*	845		196					

* mg/1 as $CaCO_3$

** measured as 6 day BOD, calculated 5 day BOD using K = 0.1

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

21 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation % Removal	D.E. Effluent	System % Removal	Floated Scum	Vac. Filt. Filtrate
PH, units	10.02		9.90	--				
BOD, mg/1	205**		195	5.03				
TOC, mg/1	272		202	25.74				
Total Solids, mg/1	919		2983	0			5514	
Volatile Total Solids, mg/1	496		562	0			2074	
Suspended Solids, mg/1	106		81	23.58			2230	102
Volatile Suspended Solids, mg/1	98		61	37.76				87
Grease, mg/1	85	88	52	38.82				
Alkalinity to pH 8.3*	123		99					
Alkalinity to pH 3.7*	285		190					

* mg/1 as $CaCO_3$

** Measured as 6 day BOD, calculated 5 day BOD using K = 0.1

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

22 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation % Removal	D.E. Effluent	System % Removal	Floated Scum	Vac. Filt. Filtrate
pH, units	--		9.85	--				
BOD, mg/l	797**		171	78.55				
TOC, mg/l	680		139	79.56				
Total Solids, mg/l	2312		3295	0			7022	
Volatile Total Solids, mg/l	1180		627	46.86			2682	
Suspended Solids, mg/l	282		87	69.15			3800	101
Volatile Suspended Solids, mg/l	280		54	80.71				60
Grease, mg/l	286	191	53	81.47				
Alkalinity to pH 8.3*	--		109					
Alkalinity to pH 3.7*	--		200					

* mg/l as $CaCO_3$

** measured as 6 day BOD, calculated 5 day BOD using K = 0.1

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

23 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation % Removal	D.E. Effluent	System % Removal	Floated Scum	Vac. Filt. Filtrate
pH, units	11.5		9.95					
BOD, mg/1	178**		107**	40.00				
TOC, mg/1	214		119	44.39				
Total Solids, mg/1	1889		2977	0			8643	
Volatile Total Solids, mg/1	549		606	0			3209	
Suspended Solids, mg/1	222		47	78.83			5915	99
Volatile Suspended Solids, mg/1	141		37	73.76				55
Grease, mg/1	55	201	44	20.00				
Alkalinity to pH 8.3*	685		120					
Alkalinity to pH 3.7*	920		210					

* mg/1 as $CaCO_3$

** measured as 6 day BOD, calculated 5 day BOD using K = 0.1

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

27 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	9.80		8.85					
BOD, mg/1	599		287	52.09				
TOC, mg/1	375		205	45.33				
Total Solids, mg/1	2518		4473	0			10489	
Vol. Total Solids, mg/1	835		710	14.97			4006	
Suspended Solids, mg/1	654		106	83.79			5240	145
Vol. Sus. Solids, mg/1	400		89	77.75				82
Grease, mg/1	363	965	110	69.70				
Alkalinity to pH 8.3*	170		45					
Alkalinity to pH 3.7*	400		195					
Ca, mg/1		1185						

* mg/1 as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

28 FEBRUARY 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	10.65		9.70		10.0			
BOD, mg/l	181		226	0	151	16.57		
TOC, mg/l	305		169	44.59	110	63.93		
Total Solids, mg/l	3655		4398	0	4333	0	14965	
Vol. Total Solids, mg/l	882		863	2.15	813	7.82	5495	
Suspended Solids, mg/l	826		73	91.16	108	86.92	9860	98
Vol. Sus. Solids, mg/l	334		60	82.03	44	86.83		64
Grease, mg/l	242		90	62.81	37	84.71		
Alkalinity to pH 8.3*	440		100		110			
Alkalinity to pH 3.7*	700		205		180			
Ca, mg/l		1275						

* mg/l as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

1 MARCH 1973

RUN 1

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	10.60		9.72					
BOD, mg/1	216		149	31.02				
TOC, mg/1	236		121	48.73				
Total Solids, mg/1	1176		4470	0			9856	
Vol. Total Solids, mg/1	411		650	0			2898	
Suspended Solids, mg/1	180		106	41.11			5310	91
Vol. Sus. Solids, mg/1	165		53	67.78				44
Grease, mg/1	140		68	51.43				
Alkalinity to pH 8.3*	285		110					
Alkalinity to pH 3.7*	475	278	200					
Ca, mg/1		990						

* mg/1 as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

1 MARCH 1973

RUN 2

Analysis	Waste To Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	9.80		9.70		9.70			
BOD, mg/1	177		169	0	113	36.16		
TOC, mg/1	156		138	11.54	108	30.77		
Total Solids, mg/1	4389		4194	4.44	2570	41.44	13069	
Vol. Total Solids, mg/1	749		704	6.01	475	36.58	4322	
Suspended Solids, mg/1	76		116	0	75	34.37	8090	144
Vol. Sus. Solids, mg/1	50		58	0	31	38.00		109
Grease, mg/1	58		69	0	48	17.24		
Alkalinity to pH 8.3*	110		115	0	100	9.09		
Alkalinity to pH 3.7*	195		200	0	180	7.69		
Ca, mg/1	843	1000	824	2.25				
Si, mg/1	5		55					

* mg/1 as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

14 MARCH 1973

Analysis	Waste To Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units	11.3		10.0		9.6			
BOD, mg/1	97		83	14.43	56	42.27		
TOC, mg/1	352		90	74.43	38	89.20		
Total Solids, mg/1	2050		2980	0	2570	0	17400	
Vol. Total Solids, mg/1	720		650	9.72	475	34.03	6660	
Suspended Solids, mg/1	264		78	70.45	24	90.91	12600	102
Vol. Sus. Solids, mg/1	195		36	81.54	16	91.79		44
Grease, mg/1	242		73	69.83	50	79.34		
Alkalinity to pH 8.3*	520		130		90			
Alkalinity to pH 3.7*	805		220		161			
Turbidity, FTU	360		70		15			

* mg/1 as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

15 MARCH 1973

RUN 1

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		9.9	9.95					
BOD, mg/l		448	383	14.51				
TOC, mg/l		320	281	12.19				
Total Solids, mg/l		4430	3390	23.48			9300	
Vol. Total Solids, mg/l		1030	940	8.74			3630	
Suspended Solids, mg/l		862	63	92.69			6130	53
Vol. Sus. Solids, mg/l		389	50	87.15				48
Grease, mg/l		234	44	81.20				
Alkalinity to pH 8.3*		175	103					
Alkalinity to pH 3.7*		450	210					
Turbidity, FTU		500	75					56

* mg/l as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

15 MARCH 1973

RUN 2

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		10.6	10.45		10.30			
BOD, mg/1		307	138	55.05	122	60.26		
TOC, mg/1		256	111	56.65	103	59.77		
Total Solids, mg/1		3410	2730	19.94	2720	20.23	13800	
Vol. Total Solids, mg/1		880	560	36.36	520	40.91	5300	
Suspended Solids, mg/1		874	52	94.05	26	97.03	11600	132
Vol. Sus. Solids, mg/1		323	42	87.00	24	92.56		71
Grease, mg/1		202	44	78.22	42	79.21		
Alkalinity to pH 8.3*		360	145		135			
Alkalinity to pH 3.7*		632	240		210			
Turbidity, FTU		650	52		20			

* mg/1 as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

16 MARCH 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		11.38	11.02		10.95			
BOD, mg/1		491	207	57.84	139	71.69		
TOC, mg/1		350	162	53.71	124	64.57		
Total Solids, mg/1		2740	1850	32.48	1840	32.85	11900	
Vol. Total Solids, mg/1		810	330	59.26	310	61.73	4100	
Suspended Solids, mg/1		743	90	87.88	33	95.56	10400	40
Vol. Sus. Solids, mg/1		365	64	82.47	32	91.23		34
Grease, mg/1		213	74	65.26	65	69.48		
Alkalinity to pH 8.3*		423	250		215			
Alkalinity to ph 3.7*		720	370		325			
Turbidity, FTU		475	85		35			

* mg/1 as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

20 MARCH 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		11.9	11.50					
BOD, mg/l		742	382	48.52				
TOC, mg/l		490	293	40.20				
Total Solids, mg/l		2379	2450	0			39263	
Vol. Total Solids, mg/l		1764	1813				14472	
Suspended Solids, mg/l		1082	188	82.62			1163	40
Vol. Sus. Solids, mg/l		444	99	77.70				28
Grease, mg/l		347	85	75.50				
Alkalinity to pH 8.3*		850	340					
Alkalinity to pH 3.7*		1188	490					
Turbidity, FTU		390	90					

* mg/l as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

21 MARCH 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		12.85	11.70					
BOD, mg/1		1670	214	87.19				
TOC, mg/1		1115	168	84.93				
Total Solids, mg/1		16995	3262	80.81			13642	
Vol. Total Solids, mg/1		16357	2934	82.06			9690	
Suspended Solids, mg/1		4438	107	97.59			10388	21
Vol. Sus. Solids, mg/1		1485	47	96.84				17
Grease, mg/1		242	93	61.57				
Alkalinity to pH 8.3*		10360	435					
Alkalinity to pH 3.7*		11300	590					
Turbidity, FTU		540	72					

* mg/1 as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

22 MARCH 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		11.70	12.75					
BOD, mg/1		588	462	21.43				
TOC, mg/1		425	322	24.24				
Total Solids, mg/1		4416	7951	0			21827	
Vol. Total Solids, mg/1		3646	7602	0			21796	
Suspended Solids, mg/1		1522	354	76.74			16288	24
Vol. Sus. Solids, mg/1		1085	166	84.70				20
Grease, mg/1		331	214	35.35				
Alkalinity to pH 8.3*		750	4820					
Alkalinity to pH 3.7*		1175	5300					
Turbidity, FTU		375	275					

* mg/1 as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

23 MARCH 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		11.35	11.55		11.55			
BOD, mg/1		778	333	57.20	199	74.42		
TOC, mg/1		528	246	53.41	149	71.78		
Total Solids, mg/1		5458	4068	25.47	3547	35.01	19507	
Vol. Total Solids, mg/1		4114	3394	17.50	2930	28.56	13522	
Suspended Solids, mg/1		1021	101	90.11	15	98.53	14392	26
Vol. Sus. Solids, mg/1		400	66	83.50	12	97.00		15
Grease, mg/1		260	126	51.54	87	66.54		
Alkalinity to pH 8.3*		475	315		310			
Alkalinity to pH 3.7*		860	460		440			
Turbidity, FTU		440	90		33			
Ca, mg/1		790	420	46.84	330	58.23		
Si, mg/1		7	7	0	6	14.29		

* mg/1 $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSES

FOR LINEN WASTEWATER TREATMENT

23 MARCH 1973

Analysis	Raw Waste to Pit	Raw Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
Ca, mg/l		790	420	46.84	330	58.23		
Mg, mg/l		1.66			1.12	32.53		
Cu, mg/l		0.27			0.14	48.15		
Pb, mg/l		0.70			0.30	57.14		
Hg, μg/l		--			--	--		
Cd, mg/l		0.04			0.02	50.00		
Zn, mg/l		0.47			0.06	87.23		
Cr, mg/l		0.06			0.03	50.00		
Fe, mg/l		2.31			0.15	93.51		
Ni, mg/l		2.10			0.15	92.86		
Si, mg/l		7	7	0	6	14.29		

TABLE C-12, CONTINUED

LABORATORY ANALYSIS
FOR LINEN WASTEWATER TREATMENT
28 MARCH 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		9.83	9.90		10.05			8.65
BOD, mg/l		425	173	59.29	161	62.12		197
TOC, mg/l		320	133	58.44	124	61.25		181
Total Solids, mg/l		6350	3560	43.94	3390	46.61	11200	2830
Vol. Total Solids, mg/l		1260	375	70.24	630	50.00	3870	630
Suspended Solids, mg/l		780	40	94.87	115	85.26	7510	58
Vol. Sus. Solids, mg/l		336	31	90.77	26	92.26		38
Grease, mg/l		193	29	84.97	40	79.27		48
Alkalinity to pH 8.3*		190	115		345			18
Alkalinity to pH 3.7*		458	220		200			155
Turbidity, FTU		460	42		28			
Ca, mg/l		1430	690	51.75	590	58.74		
Si, mg/l		51	65	0	60	0		

* mg/l as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

29 MARCH 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		9.48	9.60		9.62			
BOD, mg/l		701	318	54.64	274	60.91		
TOC, mg/l		484	231	52.27	186	61.57		
Total Solids, mg/l		6700	5960	11.04	5860	12.54	6120	
Vol. Total Solids, mg/l		1560	950	39.10	890	42.95	1070	
Suspended Solids, mg/l		562	131	76.69	97	82.74		
Vol. Sus. Solids, mg/l		381	88	76.90	70	81.63		
Grease, mg/l		118	21	82.20	24	79.66		
Alkalinity to pH 8.3*		95	83		80			
Alkalinity to pH 3.7*		331	180		173			
Turbidity, FTU		230	52		46			

* mg/l as $CaCO_3$

TABLE C-12, CONTINUED

LABORATORY ANALYSIS

FOR LINEN WASTEWATER TREATMENT

19 APRIL 1973

Analysis	Waste to Pit	Waste From Pit	Flotation Effluent	Flotation Percent Removal	D.E. Effluent	System Percent Removal	Floated Scum	Vacuum Filter Filtrate
pH, units		9.9	9.7		9.8			
BOD, mg/1		732	195	73.36	179	75.55		
TOC, mg/1		610	159	73.93	136	77.70		
Total Solids, mg/1		6040	3570	40.89	3550	41.23	47600	
Volatile Total Solids, mg/1		1660	689	58.49	660	60.24	23900	
Suspended Solids, mg/1		2210	100	95.48	39	98.24	41200	146
Volatile Suspended Solids, mg/1		900	63	93.00	25	97.22		93
Grease, mg/1		291	52	82.13	30	89.69		
Alkalinity to pH 8.3*		434	106		100			
Alkalinity to pH 3.7*		974	204		190			
Turbidity FTU		450	85		40			

* mg/1 as $CaCO_3$

APPENDIX D

INCINERATION OF LAUNDRY WASTEWATER SLUDGE

INCINERATION OF LAUNDRY SLUDGE

Reference 20 was utilized to develop an approximate operating cost for incinerating laundry sludges, due to the high cost of sludge hauling in Chicago. It was felt this mathematical model would provide adequate results for feasibility determinations. Two cases were selected for the computer program, the details of which are presented in Table D-1. The sludge fuel values were assumed, as no data on actual heat values were available. It is expected that the fuel value is quite high due to the quantity of grease present. This compared to 2,000 to 2,250 kg-cal/kg volatile solids (8,000 to 9,000 BTU/lb) for the combustible fraction of municipal refuse. Fluidized bed incineration was selected as the most suitable incineration technique for laundries, as it provides the most efficient fuel utilization of available incineration processes.

The incinerator capacity was based on a filter yield of 1680 wet kgs/hr (3700 wet lbs/hr) at a 757 lpm (200 gpm) system flow of industrial laundry wastewater containing 80% volatile solids, and 15% total solids. The computer print out results are presented in Tables D-2 and D-3 for cases 1 and 2 respectively. It was assumed for the above costs that the system operated for nine hours each day at 757 lpm (200 gpm). In both instances, the operating costs are near 60¢/cu m of wastewater ($2.50/1000 gal.), thus causing almost a 40¢/cu m ($1.50/1000 gal.) cost increase in treatment. The capital outlay of $300,000 and the short incinerator life produced excessive operating costs. Few laundries could afford a several hundred thousand dollar expenditure in addition to a wastewater treatment system. Thus, incineration was not economically feasible for sludge handling.

If it is presumed that the heat from the incinerator were recovered and used to heat effluent water from the heat exchanger from 130°F to 190°F, and if it is assumed that the laundry has No. 2 fuel oil fired boilers transferring heat at 75% efficiency, then $1.00 worth of fuel oil could be saved for each 3.78 cu m (1000 gal.) of water heated; or 21¢ cu m (80¢/1000 gal.) waste treatment costs could be recovered. This allows for 20% water loss. The net sludge handling cost is now about 45¢/cu m ($1.70/1000 gal.) wastewater treatment, still an excessive amount. This figure does not include the costs of hauling the incinerator residue either.

TABLE D-1

MATHEMATICAL INCINERATION MODEL
TEST CASE CONDITIONS

Parameter	Case 1	Case 2
Sludge Fuel Value - kg-cal/kg volatile solids	2,192	2,520
Fuel Used	No. 2 Fuel Oil	No. 2 Fuel Oil
Fuel High Heat of Combustion, kg-cal/kg	2,520	2,520
Feed Rate - wet kg/hr	1,680	1,680
Volatile Solids (VS) - %	80	80
Moisture Content - %	85	83
Fuel Cost - $/$10^6$ kg-cal	5.95	5.95
Fraction of year system used	0.27	0.27
Electric cost - $/kw hr	0.04	0.04
Maintenance labor - rate - $/hr	4	4
Service Labor rate - $/hr	8	8
Operating Labor - $/year	5,000	5,000
Ambient Air Temperature - °F	60	60

TABLE D-2

CASE 1
ON SITE FLUIDIZED BED LAUNDRY SLUDGE INCINERATION COSTS

Item	Cost - $/yr
Operating Labor	300
Fuel	11,750
Power	1,865
Total Operating Costs	13,953
Materials	367
Sand Make Up	85
Maintenance Service Labor	126
Maintenance Labor	1,179
Total Maintenance Costs	1,757

	Total Cost - $
Equipment cost including reactor, controls, wet scurbber, pumps, water clarification	260,683
Installation	26,068
Engineering fee	28,675
Total Capital outlay	315,426
Yearly Amortization Costs @ 6% interest and 7 year life	56,461

TOTAL Operating Cost = ... 68¢/cu m raw wastewater

TABLE D-3

CASE 2
ON SITE FLUIDIZED BED LAUNDRY SLUDGE INCINERATION

Item	Cost - $/yr
Labor	338
Fuel	901
Power	2,235
Total Operating Costs	3,474
Materials	367
Sand Make Up	36
Maintenance Service Labor	126
Maintenance Labor	1,179
Maintenance Costs	1,708
	Total Cost - $
Equipment Costs including reactor controls, wet scrubber, pumps, water clarification	277,728
Installation	27,773
Engineering Fee	30,550
Total Capital Outlay	366,051
Yearly Amortization Cost @ 6% interest, and 7 year life	65,523
TOTAL Operating Cost equals	67¢/cu m raw wastewater

The size of the incineration system also mitigated against its usage. The size of both incinerators of Tables D-2 and D-3 was 7.3 m (24 ft) high by 6.1 m (20 ft) by 9.1 m (30 ft). Additional area is required for a water clarification system for the wet scrubber cleaning the exhaust gases. Thus, laundry personnel now must also become involved in air pollution control and the operation of a complex air pollution control system.

Therefore, incineration is rejected for usage at the Roscoe laundry due to excessive space requirements and capital investment. For large industrial laundries able to dewater sludge to a high solids content, incineration may be a feasible process. Work is needed in developing more accurate cost figures for actual sludge fuel values and moisture contents, as well as for a wide variety of conditions in order to more firmly establish incineration costs for actual field conditions and to establish at what point incineration may be economically feasible. This could be easily done by running the same computer program at a variety of variable levels.

APPENDIX E

DEMONSTRATION SYSTEM COSTS

The following is a breakdown of the equipment and construction costs incurred for the completion of the demonstration facility.

Diatomaceous Earth Filter System

Body Feed Pump	$ 642
Valves	600
DE Slurry Mixer	614
Slurry Mix Tank	200
Precoat Pump	519
Air Release Valve	143
DE Filter	4,500
	$ 7,218

Vacuum Filtration System

Vacuum Filter	$14,550
Vacuum Pump	2,011
Sludge Conditioning Pump	888
Filtrate Water Totalizing Meter	383
Sludge Cake Pump	1,833
Sludge Conditioning Tank	599
Sludge Conditioning Tank Mixer	294
Sludge Level Control System	300
Filtrate Receiver	450
Conditioning Chemical Mixer	248
Filtrate Pump	699
Valves	300
	$22,555

Flotation System

Flocculator Tank	$ 800
Flotation System including chemical feed pumps, flow meters, valves, pressurized flow system, pumps, and tankage and all control panels	23,269
	$24,069

Miscellaneous

Sludge Tank Enclosure	$ 758
Concrete and Sewer Work	1,383
Plumbing Work	10,003
Electrical Work	4,932
Mechanical Erection	3,180
Ladders and catwalks	200
	$20,456
TOTAL	$74,298

APPENDIX F

DIAPER LAUNDRY WASTEWATER TREATMENT

DIAPER LAUNDRY WASTEWATER TREATMENT

CONCLUSIONS

1. Diaper laundry wastewater is similar in strength and appearance to linen laundry wastewater.
2. Approximately 2.5 kgs of TOC/100 kgs of diapers laundered is generated in the laundering process. Eight to nine kilograms of total solids/100 kgs of diapers washed are generated. The suspended solids generated from the washing process were about 1.4 kgs/100 kgs of diapers laundered.
3. Alum and sulfuric acid provided effective chemical treatment for old diaper laundry wastewater in this study.
4. Bench scale flotation was an effective solids separation step for the diaper laundry wastewater.
5. Disinfection of diaper laundry wastewater would be required if the water was going to be reused.
6. Diaper laundries will be forced to treat their wastewater, as other laundry types, due to hexane soluble and pH limitations.

RECOMMENDATIONS

1. Perform pilot plant wastewater treatment studies to firmly establish the characteristics of diaper laundry wastewater and its treatment as well as associated costs.
2. Obtain more extensive information on the size of diaper laundries and variation in diaper laundry wastewater characteristics in order to define the extent of the water pollution control problem and the degree of applicability of any waste treatment system.
3. Develop a diaper laundry wastewater treatment flow sheet.

4. Obtain information on the type and variability of supplies utilized by the diaper laundry industry and the effect each could have on wastewater treatment.

5. Develop water reuse feasibility information

INTRODUCTION

The laundry wastewater treatment project described in the main part of this report was funded in part by the National Institute of Infant Service, which represents the diaper laundry industry. During the course of the project, it was hoped that diaper laundry wastewater could be treated by the demonstration system. Unfortunately, this was not possible. However, during the course of the project, data about their water pollution problems was obtained from diaper laundry wastewater bench scale treatment and from an industrial survey of diaper laundry water usage. This information is presented in this Appendix to provide some insight into the diaper laundry water pollution control problem.

DIAPER LAUNDRY WASTEWATER QUALITY

On December 17, 1971, a diaper laundry in the Milwaukee area was visited for the purpose of characterizing diaper laundry wastewater. The laundry visited has an average flow of 75,700 lpd (20,000 gpd). Approximately 1636 kg (3600 lbs) of diapers are washed in a day in two washer-extractors which includes 409 kgs (900 lbs) of rewashed diapers. Thus, about 46 liters of water per kilogram of diapers (5.5 gal./lb) are utilized.

Grab samples were obtained from each machine dump for four different loads of diapers. Samples of each machine dump were composited to obtain a representative sample of wastewater for bench scale treatment tests. The samples were composited in 500 and 1000 ml fractions depending on whether the machines were at a high or low level of water. All grab samples were analyzed for total solids, total organic carbon (TOC), and pH. The composites made were subjected to rigorous chemical analysis. The volume of water utilized in each washing cycle was obtained from the plant water meter. When both washers were demanding water, it was not possible to obtain a volume. The figures that were obtained were very erratic even though the machines operated at only two levels. The first flush demanded much more water than the second flush, as the diapers were initially dry. After an extraction, a considerable amount of water was also demanded. These variations made it difficult to determine water volumes for washing cycles where volume was not measured. Those cycles that did not have a measurable water flow were estimated from the data obtained.

The results from the wastewater analysis of the individual machine dumps are reported in Tables F-1 through F-4. To the first suds is added 2.7 kgs (6 lbs) to 4.5 kgs (10 lbs) of detergent, 227 to 340 gms (8-12 oz) of

TABLE F-1

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION FOR 182 KGS OF DIAPERS (LOAD 1)

Operation	Total Solids (mg/l)	TOC (mg/l)	pH (units)
Flush	1513	535	9.05
Flush	1444	468	9.1
Extract	1350	428	9.1
Suds	4265	1382	11.9
Suds	4597	1233	12.0
Suds	4115	980	11.85
Carryover	3207	830	11.65
Bleach	3210	786	11.45
Rinse	1731	376	10.9
Rinse	1206	265	10.55
Rinse	1085	188	10.2
Extract	1174	205	10.4
Rinse	463	51	9.2
Blueing	505	88	9.35
Sour and Soften	552	87	6.3
Extract	525	72	6.75

TABLE F-2

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION FOR 182 KGS OF DIAPERS (LOAD 2)

Operation	Water Utilized (liters)	TOC (mg/l)	Total Solids (mg/l)	Suspended Solids (mg/l)	pH (Units)
Flush	--	410	1363	164	9.1
Flush	--	405	1329	167	9.1
Extract	--	360	1258	39	9.1
Suds	--	1438	4527	766	12.15
Suds	--	1553	5279	712	12.25
Suds	--	1144	5028	828	12.10
Carryover	231	851	3551	608	11.9
Bleach	--	763	3835	572	11.8
Rinse	269	309	2375	353	11.35
Rinse	674	460	1541	248	10.65
Rinse	572	215	1195	214	10.65
Extract	--	210	1268	128	10.7
Rinse	1241	75	412	103	9.65
Blueing	541	98	466	125	9.7
Sour & Soften	223	88	560	117	6.75
Extract	--	55	429	29	7.0

TABLE F-3

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION FOR 273 KGS OF DIAPERS (LOAD 1)

Operation	Total Solids (mg/l)	TOC (mg/l)	pH (Units)	Water Utilized (liters)
Flush	1514	423	8.9	
Flush	1299	345	8.95	
Suds	4152	1208	11.8	
Suds	4859	1364	11.95	
Suds	3878	988	11.85	526
Carryover	3152	498	11.75	625
Bleach	3104	694	11.6	
Rinse	2093	418	11.25	746
Rinse	1559	330	10.9	700
Rinse	1216	218	10.6	568
Rinse	467	82	9.65	
Blueing	519	94	9.55	
Sour and Soften	507	58	6.70	

TABLE F-4

VARIATION OF WASTEWATER QUALITY WITH WASHING OPERATION
273 KGS OF DIAPERS (LOAD 2)

Operation	Total Solids (mg/1)	TOC (mg/1)	pH (mg/1)	Water Utilized (liters)
Flush	1704	490	8.9	1877
Flush	1293	375	8.95	693
Suds	5172	1535	12.05	2394
Suds	4890	1495	12.10	469
Suds	4477	1245	12.0	
Carryover*	2580	678	10.3	
Bleach	3220	749	11.6	
Rinse	2155	361	11.2	
Rinse	1635	340	10.85	643
Rinse	1225	248	10.65	1646
Rinse	599	100	9.7	
Blueing	538	--	9.6	
Sour and Soften	567	--	6.5	560

* Bad sample.

bleach to the bleach cycle, 30 to 50 drops of blueing to the blueing cycle, and a sour, 227 gms (8 ounces) of antiseptic and fabric softener in the final cycle. After the addition of the detergent a large increase in pH, total solids, and TOC can be observed. The addition of blueing causes a slight increase in total solids and TOC. Addition of the rest of the supplies in the final cycle reflects a slight increase in total solids and a final pH between 6.0 and 7.0. Bleach addition also yielded a slight increase in total solids. Soap regenerator did not. In general, the wastewater contaminant concentrations tend to decrease with each succeeding cycle after the first suds.

The detergent used is an alkaline silicate, and the soap regenerator is a sodium metasilicate compound. The antiseptic utilized was a dimethyl benzyl ammonium chloride compound containing 8.5% alcohol. The sour was sodium bifluoride. The chemical characteristics of the blueing and fabric softener were not obtained.

All four wash loads sampled yielded about the same results indicating a fairly consistent type of wastewater emanating from the diapers. Based on this data, large variations in wastewater coming from the washing machine would not be expected. However, an equalization tank of some sort would be required due to the intermittence of the flow and to the relatively wide variation in wastewater quality between wash operations. In this respect, a diaper laundry is similar to all others, in that equalization is required to hold one to two hours of plant flow.

Table F-5 presents the amounts of TOC and total solids generated per 100 kgs of diapers washed. Total solids figures are reported including and not including the supplies. The calculations for this table were based on the measured water volumes for each operation. Those operations that had no direct water measurements were estimated from the other measurements obtained. It is felt these estimates are reasonable. Table F-5 demonstrates that between 5.5 and 6.2 kgs of wastewater total solids are generated by 100 kgs of diapers. The supplies added another 2.5 to 3.0 kgs of solids per 100 kgs of diapers. The amount of TOC generated by the laundering process was between 2.2 and 2.6 kgs TOC per 100 kgs of diapers laundered. The suspended solids generated amounted to only 1.4 kgs/100 kgs of diapers. This was measured for only one load. The amount of TOC generated was comparable to that obtained from synthetic shirts, pants, and kitchen towels, as are the total solids generated by the diapers with the supplies included. Thus, diaper laundry wastewater is comparable to uniform or heavy soil linen wastewater. Indeed, diaper wastes are quite similar to linen laundry wastes in appearance. A strong ammonia odor is the most readily apparent difference.

BENCH SCALE TREATMENT TESTING

Due to the difficulty in determining the exact water volumes used each wash operation, the composites that were made may not be entirely representative of a diaper laundry wastewater in view of the assumptions made. Consequently the analyses presented for the two composite samples

TABLE F-5

ESTIMATED WASTE LOADS FROM DIAPER LAUNDERING

Sequence	kgs TOC per 100 lbs Articles Laundered	kgs Total Solids per 100 kgs Diapers Laundered		kgs Suspended Solids per 100 kgs Diapers Laundered
		w/supplies	w/o supplies	
273 kg-#1	2.16	8.08	4.17	--
273 kg-#2	2.55	9.16	6.24	--
182 kg-#1	2.30	7.90	5.50	1.39

should not be taken as absolute values, but are subject to a great deal of variation due to sampling technique and differences between laundries as noted in the main report.

The two composite samples obtained were analyzed and subjected to bench scale chemical treatment and flotation tests. Analyses of the two composites appear in Table F-6. From this table, it can be seen that the BOD is slightly higher and the suspended solids of the composite samples about the same as that of raw sewage. Therefore very little surcharge impositions would be expected at this particular laundry based on these samples. Grease content and composite pH may be a problem in some municipalities dependent on their sewer discharge ordinances. Some communities may allow a discharge of water with a pH of 10.5, others only a pH of 9.0. This problem is regional in nature. The grease content is sufficiently high to conflict with almost all sewer ordinances, as they usually allow only between 50 and 150 mg/l of grease to be discharged. Thus, in some instances, neutralization and a solids separation step may be required for diaper laundry waste treatment. If the water were to be reused, disinfection would be required due to the presence of viable coliform organisms. Most of these organisms probably came from the flushing operations where no detergent and relatively cool water are utilized. The carryover of subsequent disinfectants and hot water is apparently not enough to kill them all. Approximately 3 x 10^6 coliforms/ml were measured in the first flush. It would be expected that the flushes could be bypassed if wastewater reuse were to be attempted.

Chemical treatment tests performed on the composites showed that alum ($Al_2(SO_4)_3 \cdot 18H_2O$) by itself or anionic and nonionic polyelectrolytes by themselves did not properly treat the waste. Ferric chloride and calcium chloride were able to form floc particles, but alum in conjunction with sulfuric acid provided the most effective chemical treatment. Neutralization of the wastewater to a pH of 8.5 followed by flocculation of the waste for two minutes after addition of 700 mg alum/l and 1 mg/l of a nonionic polyelectrolyte to strengthen floc provided good chemical treatment.

The samples obtained were not tested until ten days after they arrived in the laboratory. Consequently, the age of the samples may have affected the chemical treatment characteristics of the waste, as it did for linen wastewater. Calcium chloride may have proved to be the most effective coagulant had the samples been tested fresh. The presence of a large amount of silica and the similarity of the diaper wastewater to linen wastewater suggests that this is the case.

Nonetheless, four bench scale flotation tests were performed utilizing the alum-acid treatment, the results of which are presented in Table F-7. This table demonstrates that good effluent quality was obtained. Approximately 75% of the TOC was removed and 80-90% of the suspended solids. Effluent clarity was almost that of tap water. With proper disinfection, it probably could be reused within the laundry without

TABLE F-6

WASTEWATER CHARACTERISTICS OF DIAPER LAUNDRY COMPOSITES OF 12/17/71

Analysis	400 lb Composite	600 lb Composite
Total Solids - mg/l	1667	1803
Total Volatile Solids - mg/l	668	812
% Total Volatile Solids	40	45
Suspended Solids - mg/l	290	279
% Suspended Volatile Solids	100	100
TOC - mg/l	363	443
Soluble TOC - mg/l	171	222
BOD - mg/l	462	664
Total Phosphorus as P - mg/l	32	28
pH - units	10.3	10.5
Grease - mg/l	306	349
Alkalinity - mg/l as $CaCO_3$	690	825
Mercury - μg/l	<1	<1
Lead - mg/l	0	0
Silica - mg/l as SiO_2	255	270
Ammonia Nitrogen - mg/l as N	41	41
Kjeldahl Nitrogen - mg/l as N	129	129
Iron - mg/l	0.3	0.4
Total Coliform/100 ml	490,000	2,200

RESULTS OF BENCH SCALE FLOTATION TEST FOR DIAPER LAUNDRY COMPOSITES OF 12/17/71

Sample	400 comp	400 comp	600 comp	600 comp
Test No.	1	2	3	4
H_2SO_4 Dosage, mg/l	294	294	327	370
Alum Dosage, mg/l	700	700	700	700
Nonionic polyelectrolyte dosage, mg/l	1	0	1	1
pH after H_2SO_4 Addition	8.6	8.6	8.75	8.45
Recycle Rate , %	33	33	33	33
Rise Rate, mpm	0.12	0.21	0.43	0.43
Detention Time, min.	8	8	8	8
Scum Volume, 1/1000 1	80	80	80	80
Settled Solids, 1/1000 1	0	0	0	0
Effluent Suspended Solids, mg/l	27	56	70	19
Effluent Total Solids, mg/l	1450	1482	1606	1556
Effluent TOC, mg/l	82	95	109	82
Effluent pH	6.1	6.1	6.3	6.2
% Suspended Solids Removal	91	81	75	93
% TOC Removal	77	74	75	81

harming the diapers. Without the use of a polyelectrolyte, effluent clarity and suspended solids are impaired, as shown by comparing Tests 1 and 2. Fairly high rise rates were observed in three of the tests, indicating a flotation unit would not have to be overly large.

Thirty-three percent recycle proved adequate, and waste treatment produced 80 liters of scum per 1000 liters of wastewater. Noting the cost of hauling liquids, it would be desirable to reduce this volume. However, the comments presented in the main report regarding alum sludge dewatering are equally true for this wastewater. In regard to the treatment concept, it is beneficial to consider attempting to utilize calcium chloride for chemical treatment in order to produce a scum that is readily dewaterable, if costs are to be kept reasonable and sludge handling is not to become a problem. In general, the waste treatment scheme required for diaper laundries should not have to be much different from that of linen laundries. Work is required in trying to adapt the treatment process outlined for linen laundries to the diaper industry, because the wastewater characteristics are different, and the wastewater will require treatment due to the hexane soluble and pH levels. Heavy metals were not a problem.

INDUSTRY WASTEWATER SURVEY

Table F-8 summarizes the results of 20 usable diaper laundry industry survey forms that were sent to the Envirex office for analysis to obtain information on diaper laundry water costs, consumption, and sewer expenditures (see Appendix A). Due to the relatively small number of laundries reporting, the figures presented cannot be taken as absolute. However, the water and sewer costs reported are about the same as for other laundries, which would be expected. Only one laundry reported a sewer surcharge, and it was very low. Looking at the wastewater analyses reported for BOD and suspended solids and noting the results obtained from the composite samples obtained, it appears that diaper wastes are of lower strength than linen laundries, and consequently, sewer surcharges do not appear to be a problem for diaper laundries.

Table F-8 demonstrates a large variation in diaper laundry size and water consumption. It is evident that diaper laundries come in a wide variety of sizes with an average water usage of 204 cu m per day (54,000 gpd). This is generally lower than other laundry types. The data also indicated a larger amount of water consumed per kg of diapers laundered than for other laundry types. This could well be attributed to the small amount of data. Washroom costs tended to be lower for diaper laundries, and would be expected to some degree since there was no sewer surcharge indicated. In general, the cost and consumption of water by diaper laundries is not greatly different from that of linen and industrial laundries.

A good relationship between laundry size and water consumption was obtained, as demonstrated in Figure F-1. The correlation of the two variables was an excellent one. A least squares regression line is

TABLE F-8

AVERAGE WATER USAGE AND WATER COSTS FOR 20 DIAPER LAUNDRIES

Item	Range	Average	No. of Responses
Raw Water Cost (¢/cu m	3.4-12.4	6.9	18
Sewer Charge (¢/cu m)	0-7.4	4.0	10
Sewer Surcharge (¢/cu m)	--	0.8	1
Water Consumption (1000 lpd)	42-662	204	16
Liters Water Consumed/ kg diapers washed	28.3-57.5	45.8	11
1000 kgs diapers washed/wk	1.2-75	16.4	19
Total Laundry Size (1000 kg/week	6.8-93	25	18
Total Washroom Costs (¢/cu m)	5.5-19.6	10.6	10
Washroom Costs (¢/100 kgs laundered)	24-81	51	8
Wastewater BOD - (mg/l)	200-486	342	2
Wastewater Suspended Solids (mg/l)	120-553	372	3

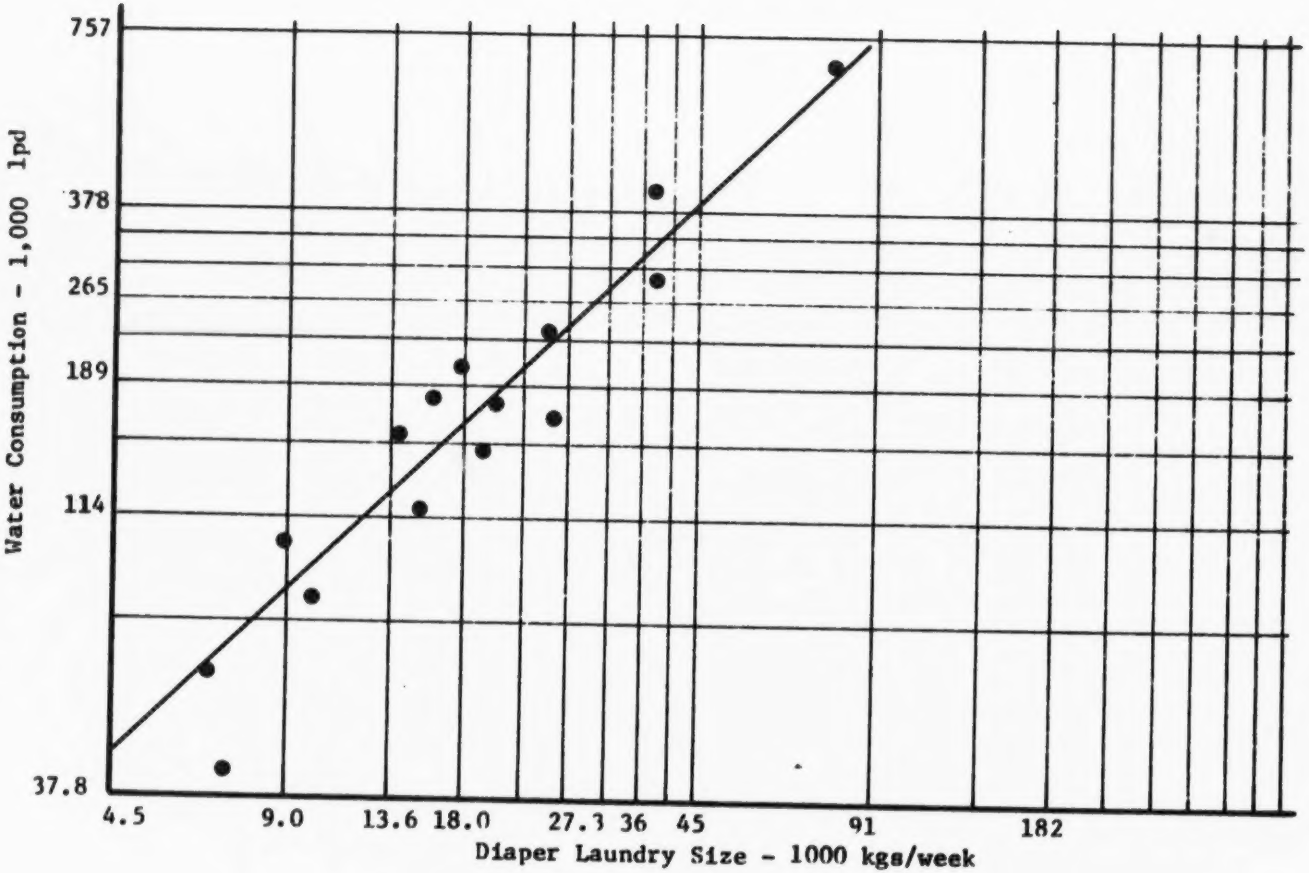


FIGURE F-1
DIAPER LAUNDRY WASH LOAD VS. WATER CONSUMPTION

drawn on the curve with a correlation coefficient of 0.97 calculated for this line. The slope of this line is 43.3 liters of water/kg of diapers (5.2 gal/lb) laundered. No correlations were demonstrated between water consumption and cost or water consumed per unit weight washed and laundry size. A summary of the 20 responses obtained is presented in Table F-9.

DIAPER LAUNDRY WASTEWATER TREATMENT REQUIREMENTS

From the foregoing and the general results obtained from all laundry studies, it is evident that wastewater treatment is going to be needed by many diaper laundries. It is feasible based on the bench test results of this study and on the results of the linen laundry wastewater testing. Consequently, diaper laundries have to be prepared to install treatment systems and incur operating costs comparable to that of linen laundries, e.g. 20¢ to 40¢/cu m of wastewater treatment (75¢ to 150¢/1000 gal.). The wastewater treatment system installed will have to be capable of reducing hexane solubles below 100 mg/l as well as significantly reducing suspended solids. In certain instances, flotation will provide the necessary degree of treatment while other instances will require diatomaceous earth filtration. Diatomaceous earth filtration should be a viable process for the diaper laundry industry considering the low suspended solids concentration of the wastewater.

Information is needed for diaper laundry wastewater treatment on a pilot plant basis to conclusively determine what coagulants can be utilized, the dewatering characteristics of diaper scum, the allowable flotation tank hydraulic loadings, and operating and capital costs for wastewater treatment. As it stands, only rudimentary conclusions regarding treatment characteristics and costs can be drawn. There is enough difference between diaper laundry and linen laundry wastewater bacteriologically and in nutrient content, as demonstrated in Table F-6 (note high phosphorus and nitrogen contents), that significant differences in wastewater treatability on a continuous basis could manifest themselves. It is a demonstrated fact that phosphorus can interfere with the coagulation process as pointed out by Stumm and O'Melia (1). Therefore, it is strongly urged that work be undertaken in the area of pilot plant treatment to establish diaper laundry wastewater treatment system design parameters. This will show to what degree diaper laundry wastewater may be likened to linen wastes. The degree of applicability of wastewater treatment could not be determined by this cursory study.

TABLE F-9

DIAPER INDUSTRIAL SURVEY RESPONSES REGARDING WATER CONSUMPTION AND COST

No.	Raw Water Cost (¢/cu m)	Sewer Charge (¢/cu m)	Sewer Surcharge (¢/cu m)	Size (1000 kgs diapers Laundered/week)	liters Water Consumed/ kg laundered	Water Consumption (1000 lpd)	Total Wash-Room Costs (¢/cu m)
1	6.9	--	--	3.9	--	238	--
2	5.0	7.1	0	17.7	57.5	204	12.2
3	12.4	--	--	37.3	54.1	405	--
4	10.0	--	--	1.2	--	153	--
5	4.0	4.5	0	6.8	56.6	102	8.5
6	11.4	7.4	0.8	20.5	42.5	174	19.6
7	7.1	5.3	0	4.9	--	167	12.4
8	10.0	4.5	0	6.6	45.0	61	14.5
9	5.0	3.7	0	7.3	28.3	42	8.7
10	6.9	1.8	0	7.2	--	--	8.7
11	7.7	--	--	--	--	--	--
12	5.5	--	--	19.5	36.7	144	--
13	3.4	2.1	0	15.9	53.3	180	55
14	5.8	--	--	4.5	--	116	--
15	5.3	--	--	10.0	40.8	81	
16	5.3	4.0	0	38.2	38.3	291	9.2
17	--	--	--	75.9	--	--	--
18	7.1	0	0	36.4	--	662	7.1
19	--	--	--	8.9	--	--	--
20	7.7	--	--	25.3	46.6	235	--

REFERENCES

1. Stumm, W. and O'Melia, C. R. Stoichiometry of Coagulation, Journal American Water Workds Assoc. 60:568 (1968).

APPENDIX G

ENGLISH-METRIC CONVERSION TABLE

To Convert	TO	Multiply By
BTU	kg-cal	3.968
cfm	cu m/min	0.0283
cm	in.	0.394
cm	ft	0.0394
cu cm (ml)	cu ft	0.0000353
cu ft	cu m	0.0283
cu ft	cu cm	28,320
cu m	cu ft	35.31
cu m	gal.	264
cu m	cu yd	1.31
cu m/min	cfm	35.31
cu yd	cu m	0.765
ft	m	0.305
ft	cm	25.4
gal.	l	3.785
gal.	cu m	0.003785
gm	lb	0.0022
gm/cu cm	lb/cu ft	62.4
gpm	lpm	3.785
gpm/sq ft	lpm/sq m	40.7
in.	cm	2.54
kg	lb	2.20
kg-cal	BTU	0.252

To Convert	to	Multiply By
kg/day/sq m	lb/day/sq ft	0.205
kg/sq cm	psi	14.3
kg/sq m	lb/sq ft	0.205
kg/sq m/hr	lb/sq ft/hr	0.205
l	gal.	0.264
lb	kg	0.454
lb	gm	454
lb/cu ft	gm/cu cm	0.016
lb/day/sq ft	kg/day/sq m	4.88
lb/sq ft	kg/sq m	4.88
lb/sq ft/hr	kg/sq m/hr	4.88
lpm	gpm	0.264
lpm/sq m	gpm/sq ft	0.245
m	ft	3.28
metric ton (1000 kg)	ton (short)	1.10
psi	kg/sq cm	0.0703
sq ft	sq m	0.0929
sq m	sq ft	10.76
ton (short)	metric ton (1000 kg)	0.907